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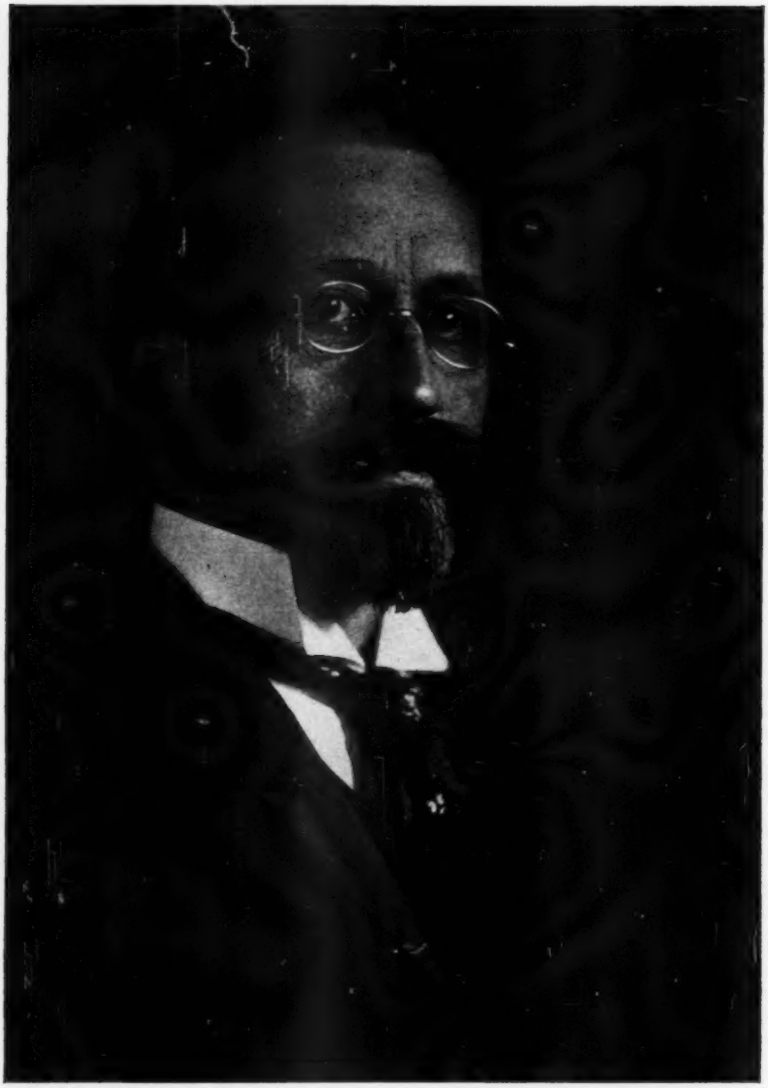

RALPH STOCKMAN TARR

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MEANDERING VALLEYS AND UNDERFIT RIVERS

W. M. DAVIS

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Underfit Rivers.—The chief object of this paper is to call attention to an explanation recently suggested for the peculiar relation that is frequently observed between the small-curved meanders of a river and the larger-curved meanders of its valley, a relation that has been called "underfit." Some geographers have doubted whether there was anything peculiar or abnormal enough in such a relation to demand special explanation; others believe that an underfit river must once have been of larger volume, so that its meanders could be of the same dimensions as those of the valley, and that the river after carving

the larger curves of its valley suffered loss of volume, as by beheading, climatic change, or some other cause. Evidently the underfit relation can occur only after a sufficiently advanced stage of valley development for the opening of a floodplain in the valley bottom, and before so far advanced a stage that the valley sides have lost distinct expression; that is, in full and late maturity; for during youth, before a floodplain is formed, the valley sides descend directly to the river banks and leave no space in which the curves of the river can depart from those of its valley; and in old age, after the valley sides have wasted away, there are no longer any valley meanders with which the river meanders may be compared.

Lehmann's Principle.—A new explanation of the underfit relation of a small-curved river to a larger-curved valley has lately been offered by Dr. Otto Lehmann of the University of Vienna. He told me of it during an inter-university geographical excursion in France in the spring of 1912, and has since then, when about to publish an account of it himself, authorized me to make such statement of it as may seem desirable. In now presenting it to American geographers, I wish to propose that the principle involved should be called—by those who are interested in the historical development of our science—Lehmann's principle, just as the production of coastal embayments by the partial submergence of a dissected land surface may be called Dana's principle; and the frequent dependence of flights of river terraces on defending rock ledges, Miller's principle; and so on. Lehmann's explanation is, in brief, that the failure of the curves of a river to fit the curves of its maturely opened valley is due to a gradual loss of volume by reason of an increasing underflow in the accumulating alluvial deposits which the river itself lays down on the widening valley floor, and of an increasing percolation through slowly widened crevices and passages in the underlying rocks. Lehmann's principle is therefore that rivers normally and spontaneously diminish in volume during maturity, because the alluvial underflow and the deeper underground percolation as normally increase. Before giving further account of this ingenious idea, a general statement regarding the evolution of river meanders and of incised meandering valleys will be introduced, in order to enter upon Lehmann's explanation of underfit rivers on the basis of a clear understanding of the points involved in it.

Initial Irregularity of River Courses.—There has been a needless amount of discussion of the origin of river meanders based on the false assumption that the initial course of a river is a straight line. No straight river occurs in a state of nature. Any young consequent river, newly established on a land surface not previously subjected to river action, must inevitably have an irregular initial course due to the unavoidable inequalities of the land surface. Such a land surface

may be a newly uplifted sea floor, a lake bed revealed by the withdrawal of the lake waters, a recent lava flow, or a drift sheet laid bare by the melting of a continental glacier. All such surfaces have sufficient inequality to give the consequent rivers which are established upon them some significant departures from the most unnatural of all courses, a straight line. It may be pointed out that a revived river on an uplifted peneplain does not here enter our problem, for it does not assume a new initial course, as some writers have implied. Such a river begins its new cycle of work along the course that it had developed when uplift interrupted the preceding cycle—except in the unusual case of uplift with so pronounced a tilting or warping that the pre-existent rivers are turned into new courses consequent on the new slant given to the uplifted surface; courses of this latter origin must necessarily be irregular and might be here considered; but they are rare and will therefore not be considered further.

Inasmuch as the initial irregularities of a young river are unsystematic, in the sense of having no relation to what may be called the intention or preference of the river that for a time adopts them, they have as yet received no special name. They will be here referred to as bends or turns. It is evidently not desirable that they should be called meanders; that technical term should be reserved for the rather systematic curves later developed by the action of the river itself and appropriate to its habit of flow.

Development of Initial Bends into Systematic Curves.—The path of the fastest current in a river departs from the medial line or axis of its channel, where it would flow if the river were straight and of symmetrical cross-section, toward the outer side of every bend; that is, toward the concave bank. Lateral erosion will therefore be stronger along that bank than along the opposite or convex bank, and the greatest depth of channel will be near the concave bank. Lateral erosion thus initiated will accompany downward erosion from the very beginning of the river's activity. Indeed if the velocity of a river is greater while reducing the fall of its too steep course during youth than afterwards when it attains a graded course of less fall in maturity, the centrifugal force expendible in lateral erosion during youth may be greater than in maturity; but the rate of lateral displacement of the river by lateral erosion will ordinarily be greater in late maturity when it takes place chiefly in unconsolidated alluvial deposits of the floodplain, than in youth when it takes place in the valley-side rock. In any case it is a mistake to say, as is sometimes said, that lateral erosion does not begin until after vertical or downward erosion has ceased. Instances may be pointed out in which, during a vertical erosion of a hundred feet or so, the lateral erosion of a river has been five or ten times as much.

The initial bends or turns of a river undisturbed by external accidents will be slowly expanded by lateral erosion, while the valley is slowly deepened by vertical erosion; and more or less of the eroded material will be laid down along the convex banks down stream from its source, as the river shifts laterally away from the convex toward the concave banks. Thus the initial sinuosity of the river course is spontaneously increased. As centrifugal force varies inversely with curvature of path, initial bends of short radius will usually be expanded more rapidly than those of long radius, and thus a similarity of curvature may be developed from many dissimilar curves. But it must not be assumed that every river expands every bend of its initial path; large rivers may soon obliterate the small bends of the channels and expand only the larger ones; none but small rivers will take such heed of all the little bends of their channels as to break up a large, slightly irregular bend into many small ones. This again tends to bring about a similarity of curvature, large rivers developing large curves and small rivers small ones. It must not be assumed that an increase over initial irregularity always involves an increase in radius of curvature; a gentle bend of long radius may be more worn by a good-sized river in one part of its arc than another, so that its long radius of curvature is for a time shortened; and this in a third manner tends to produce a similarity of curvature in bends that were initially dissimilar. Hence if a river acts without interference from external disturbances it should exert a selective action, whereby initial bends of many different patterns are brought towards a uniformity of curvature, and whereby a rough relation is established between size of river and size of curve. When this stage of progress towards organized development is accomplished, the further work of the undisturbed river will tend to enlarge its curves in arc as well as in radius; and the curves will then begin to deserve the name of meanders. Thereafter the belt included between lines drawn tangent to the curves, on the right and left of the general river course, may be called the meander belt.

THOMPSON'S PRINCIPLE.—Geographers have left it for a noted physicist, Professor James Thompson, of England, to point out an essential detail in the action of undisturbed rivers in meandering courses, whereby their meanders are systematically enlarged. His essay was entitled: "On the Origin of Windings of Rivers in Alluvial Plains" (Proc. Roy. Soc., London, xxv, 1876, 51), but its principle applies to winding rivers in their youth as well as in their maturity. On account of the centrifugal force of the flowing water, the curved river cannot have a level surface: the water must be slightly higher at the outer or concave bank than at the inner or convex bank. The greater the velocity of the river and the shorter the radius of its curves, the more pronounced must be the slant of its surface. But the bottom

water, moving more slowly than the surface water on account of friction, will not have sufficient centrifugal force to withstand the greater pressure exerted upon it by the higher water near the outer bank, and will therefore be given a component of motion toward the inner side of each curve; and in virtue of this it will flow obliquely across the bottom toward the inner bank. This will lower the water surface near the outer bank; and thereupon the surface water will gain an outward component of motion, and its flow will be directed obliquely toward the outer bank. The oblique motions thus instituted will aid in the erosion of the outer bank and in the transfer of the eroded material towards the inner bank.

Down-stream Migration of Meanders.—The enlargement of river meanders does not take place equally all along the outer bank of each curve. As a river flows into a curve, a certain time is required for the advancing current of fastest flow to be fully displaced toward the outer bank; hence outward erosion does not begin in full strength at the beginning of the curve. Similarly at the end of a curve, a certain time is required for the displaced line of fastest flow to regain its medial position; hence work on the eroded bank is continued beyond the end of a curve. If the curves are close set without connecting tangents, the line of fastest current, when it enters a curve to the right, will still have the lateral displacement due to its passage around the preceding curve to the left. The right-hand curve will therefore, under these conditions, be eroded on its inner or convex bank for a little distance beyond its beginning. The failure of the river to begin erosion of the outer bank at the beginning of a curve and the tendency to continue erosion of a given bank into the next curve result in the slow displacement of all the curves down the river valley. A young river must therefore, as soon as its initial bends are developed into somewhat systematic curves or meanders, be conceived as not only deepening its valley, but also as enlarging every curve, widening the meander belt, and pushing the whole system of curves down-valley. The down-valley migration of meanders, as it may be called, has probably been long known to engineers, but it has only lately found its way into text books of physical geography. It would be interesting to learn who first announced this principle.

Amphitheaters and Spurs.—If vertical erosion is now more explicitly taken into account along with lateral and down-valley erosion, it will be seen that a valley eroded by a young consequent river of well-defined curves must possess a number of systematically related features. The river may still be interrupted by frequent rapids, between which graded stretches will have been developed: but even at this early stage under-cut, steep-walled amphitheaters will be excavated around the outside of each curve, alternately right and left; and into

each amphitheater a sloping spur will descend from the opposite valley side. This is a well-established and familiar matter, truly, yet not so fully used in the description of valleys as its systematic value warrants. Because of the down-valley migration of river curves, a steep amphitheater wall will begin on its up-valley arm and not reach its full height for a moderate distance beyond the beginning of its concave curve. It will also extend with decreasing height around the end of its curve and along the up-valley side of the next spur, which will be undercut and steepened down to river level. Each spur will therefore be trimmed off along its up-valley side, while its down-valley side will have a gentler slope where the river has withdrawn or slipped off from it; the slopes on the two sides of a spur may therefore be called the undercut and the slip-off slopes. As a result of this dissimilarity of form, the aspect of a young or early mature meandering valley will be different according as the observer looks upstream or downstream. In the first case the gentle slip-off slopes may show a succession of cultivated fields; in the second the abrupt undercut slopes may show a succession of wooded scarps. The gentlest slope of a spur will usually be along its axis, about at right angles to the general course of the valley; its declivity will give a good indication of the ratio between lateral and vertical erosion during the period of valley deepening; and as noted above this ratio may be as large as five or ten to one. The axial and slip-off slopes of the spurs may be thinly covered with river-worn gravels and sands, irregularly strewn and obliquely bedded; no such deposits are to be expected on the undercut slopes of the spurs and amphitheaters. Excellent examples of undercut spurs are given by Marbut, who notes the widening of the meander belt, but apparently does not recognize the down-valley migration of the meanders (Missouri Geol. Survey, vol. x, 1896, 104-107).

Development of Floodplains.—A consequent river will eventually wear down its ungraded rapids and deepen its valley along the greater part of its length sufficiently to establish a continuously graded course, in which all the previously graded stretches, now more deeply degraded, are united; and on which its capacity to do work, in the way of eroding its banks and of transporting its load, will just equal the work that it has to do. It may then be regarded as passing from youth to maturity. Further change in the fall of the river is very slow; yet it must take place, even though the river still maintains a graded condition; for the river volume, which is a factor in carrying power, and the load which has to be carried, are both variable quantities. If the load increases during maturity because of increasing ramification of side streams, the valley floor must be slightly aggraded in order to maintain the balance between carrying power and load; later on, when load decreases with the decrease of relief in the approach of old

age, the valley floor must be slowly degraded—unless compensation is accidentally maintained by a loss of river volume due to decrease of rainfall with waning altitude of drainage area, as the theory of the cycle of erosion demands, and to withdrawal by underflow and percolation, as Lehmann's principle suggests. These slow changes of valley depth may, however, be neglected for the present, while we consider the further effects of lateral erosion, whereby the valley floor is widened.

The river is assumed to be still working in the enlargement of the fairly regular set of curves, previously developed, and to work undisturbed by external agencies. The enlarging curves will better and better deserve the name of meanders as their arc increases. The river will continue to undercut the amphitheater walls and the up-valley sides of the spurs; but as valley deepening has now practically ceased, the lateral shift of the river will withdraw it horizontally from the base of the axial and slip-off slopes of the spurs, and sediments will thereupon be laid down to fill the evacuated space; for there the water runs slowest, and unless the space were filled the cross-section of the river would increase, its velocity would decrease, and the graded condition would be destroyed. Strips of floodplain will thus be systematically developed along the convex banks, alternately right and left, around the end and along the down-valley side of the spurs. The strips, narrow at first, slowly gain in width; they are gracefully curved upstream at their spur-end beginning, and down-stream at their end under an amphitheater wall. Their pattern suggests that they should be called scrolls; they may be described as narrow or wide, according to their stage of growth. As a result of the down-valley meander migration, the tributary streams, that may have once entered the river at the end of a spur or a floodplain lobe, will in time be overtaken by the next up-stream meander and will enter its outer curve (See note in Geol. Mag., London, 1903, 145-148).

Changes in Amphitheaters and Spurs.—Along with the widening of the floodplain scrolls, the amphitheaters must be enlarged, elongated and opened, and the spurs must be more and more undercut and consumed. At first during the deepening of the valley, when but little of the original breadth of the spurs has been lost, they may be called trimmed; later on, when floodplain scrolls are widening and the originally rounded end of the spurs is narrowing to a cusp, they may be called sharpened; still later, when they have nearly disappeared, perhaps blunted is as good a term as any other. At the same time the amphitheaters are elongated by the down-valley advance of the river meanders; and the elongated amphitheaters are opened by the consumption of the separating spurs. Let it be noted in passing that the three terms trimmed, sharpened, and blunted, have an evolutionary

value, in implying that the trimmed spurs were once wider, that the sharpened spurs were once duller, and that the blunted spurs were once sharper; they are therefore explanatory, not empirical terms. Likewise, the terms, elongated and opened as applied to the amphitheaters are explanatory. Blunt, sharp, long and open are empirical terms.

Widening of a Floodplain.—The further progress of undisturbed river work after the blunting of the spurs and the opening of the amphitheaters involves a slow widening of the valley floor to a greater width than that of the meander belt, so that the river shall no longer swing against the two valley sides at every double meander. It thereafter undercuts one side here, the other side there, in irregular instead of in systematic fashion. Its course thus comes to wind more and more freely through the widening floodplain, and at last swings but rarely against the valley-sides. Changes in its course are then much more rapid than when it was working against rocky side-walls. The lower Mississippi is now in this late stage of development. Jefferson has examined the maps of a number of rivers with respect to the "Limiting Width of Meander Belts" (Nat. Geog. Mag., 1902, 373-384), and finds that on open floodplains the width of the meander belt averages eighteen times greater than that of the river.

Cut-off Meanders.—It has been assumed, and with good reason, that during all the time of undisturbed meander development, the river has been sweeping smoothly around every meander curve and expanding all the curves in thoroughly competent fashion. Many rivers do flow and work in this fashion. Each meander must slowly grow to greater and greater size, increasing in arc as well as in radius, until the neck of a valley-side spur or of a floodplain lobe is narrowed and worn through. Then the roundabout meander is cut off and abandoned; the river adopts the shorter course instead of continuing on the longer one. The river length, thus far slowly increasing, then suffers a sudden loss equal to the perimeter of the cut-off meander. Cut-offs may occur during the youthful stage of a narrow, deepening valley, as well as in the mature stage of a graded and broad-floored valley. In the former case, the continued deepening of the valley after the cut-off has been made will soon leave the abandoned roundabout valley curve above the river level. The Meuse in northeastern France shows good examples of this kind; two examples are reproduced from the Etat-major map of France in my Geological Essays (p. 597).

A new meander will be gradually developed to replace the lost one, and this reproductive process may involve a somewhat systematic series of changes, as has been shown for the Mississippi by W. S. Tower in a study of "The Development of Cut-off Meanders" on the Mississippi (Bull. Amer. Geog. Soc., 1904). Hence an undisturbed meandering river ought to pass through periods of gradually increasing

length alternating with moments of sudden decrease, the variation in length thus caused being confined within fairly constant limits. This is certainly true for the Mississippi. When a cut-off occurs on a floodplain and the meander is left as an ox-bow lake, it will usually possess a radius of maximum length; the other meanders, not yet enlarged to the cut-off stage, are therefore as a rule of smaller radius than the ox-bows. The meanders and ox-bows of the Mississippi confirm this expectation.

Meanders of Large and Small Rivers.—The attainment of a freely meandering course on an open floodplain will of course demand a longer time from a small river working in hard rocks than from a large river working in unconsolidated sands or clays; but under the undisturbed conditions here assumed even a small river must eventually fulfil its destiny of enlarging all its curves, one after the other, to the cut-off stage. It will mature more slowly than a large river, but the features of maturity should be much alike in both cases, except in dimensions. If there be important differences in actual examples of large meandering and small meandering rivers, the differences are more likely due to the greater number of accidental disturbances by which a small stream is disturbed during its slow and feeble development, than to any inherent difference in the principle of undisturbed meander development as applied to streams of different size. A small undisturbed river must expand its meanders to larger and larger radius and longer and longer arc, until cut-offs prevent further enlargement. Wherever the meanders are far enough separated to have free space for growth—and certainly they ought sometimes to be wide spaced in small rivers, if they originated only in the initial irregularities of the river's course—they ought to attain a large radius of curvature even in a small river. But the fact that small rivers do not have large-curved meanders indicates that the conditions of no disturbance, here assumed, do not occur; thus we approach a principle of prime importance—namely, that the small meanders of small rivers and the large meanders of large rivers are not so much the result of the river's own action, as of its reaction to the external disturbances to which rivers are subject If initial bends and turns are treated as external disturbances, acting in the ways already explained, this principle will be all the more completely assured. Hence our next problem is to consider the nature of external disturbances and their effect on river behavior.

Variations in Rock Resistance.—Freedom from external disturbances, thus far assumed, is unnatural. No river is left free to develop meanders according to its own intention. One of the commonest external influences is found in diversity of rock resistance along a river course, whereby lateral as well as vertical erosion is made easier in

one stretch than in another. The variety of disturbing conditions thus introduced is so great that no general treatment will cover all of them; each case must be discussed for itself. Yet unless contrasts of rock resistance are wide-spaced and pronounced and the river is small and feeble, the effect of varied rock structures, acting alone, is comparatively small as far as the forms of meanders is concerned. Thus in the highland of the Ardennes, composed of greatly deformed and somewhat unequally resistant rocks, the deeply incised meanders of the Meuse are finely developed; those of the Ourthe and Semois are still more remarkable in the perfection of their curvature and the length of their arcs. It does not seem possible that these extraordinary meanders, which must have begun their development much above the depth to which they are now incised, should be determined to any significant degree by the folds of the deformed strata, as has been suggested, or by inequality of resistance.

Pronounced but close-spaced differences of rock resistance may possibly cause local exaggerations of meander curves: for if a weak structure happens to lie on the outside of a curve, the curve may be locally expanded into it. It may, however, be doubted if this is a frequent cause of meanders; for a local expansion of a curve would soon be checked by river-swept gravels, after which its further enlargement would be slow; just as a local deepening of the channel in weak rocks usually comes to be gravel-covered when the river course through it is graded. In both these cases, the next down-stream strong rocks exercise a large control on the amount of erosion that the river can accomplish in the adjoining weak rocks.

When variations of rock resistance are strong and wide-spaced, they will produce the familiar result of accelerating river development in the weaker structures and retarding it in the harder structures; thus a maturely developed series of floodplain scrolls, systematically placed in relation to the accompanying amphitheaters and spurs, may be already formed where a river traverses a wide belt of weak rocks, while the same river, farther down stream in more resistant rocks, is still in the youthful stage of valley deepening, without any floodplain.

Anomalous River Meanders.—Marbut calls attention to the sharpening of meanders into cusps where lateral erosion is facilitated by the entrance of a small tributary valley (Missouri Geol. Survey, vol. X, 1896, p. 109). Peculiar kinks, for which no explanation is current, are mapped in the free meanders of the Theiss on its broad floodplain in central Hungary: one of its branches, the Koros, is so excessively sinuous that the meander belt itself meanders.

An altogether exceptional case is offered by the Connedogwinet, a branch stream which enters the Susquehanna from the west near Harrisburg. It flows in a mature valley of half-turn meanders incised to

a moderate depth beneath a peneplain; the valley floor has a floodplain a few hundred feet wide. One striking feature of the case is the excessive length of the rectilinear tangent by which the half-turn meanders are united; another is the path of the stream along the base of the slip-off slopes of the spurs, and hence on the up-valley side of the floodplain scrolls, while the floodplain scrolls lie along the undercut spur slopes. So far as I know, attention has only once been called to these features as abnormal departures from the systematic habits of most rivers in incised meandering valleys (Proc. Amer. Phil. Soc., xli, 1902, 251); no satisfactory explanation for them has yet been offered.

Landslides, Tree-Falls and Sod-Slips.—Among the most common accidents by which the regular growth of river meanders is disturbed is the invasion of the river channel, particularly on the concave bank, by sliding rock-waste, falling trees and slipping sods. Young rivers, deeply incised in a highland, are frequently more or less clogged in their narrow channel by landslides, rock-falls, talus cones and delta fans, whereby the development of smooth curves, alternately right and left, is much embarrassed and may be entirely checked. Such rivers are battered about, now on this side, now on that, and hence have no opportunity of developing serpentine courses. The comparatively rectilinear course of certain rivers, deeply intrenched in elevated highlands, is perhaps due to the impediments which landslides from undercut slopes and inwashed waste from side ravines have offered to an expansion of the bends and turns with which the river began its work. If this supposition be permissible, we may imagine cases in which the initial bends and turns, instead of being expanded during the incision of a deep-cut valley, are diminished and possibly extinguished. The ratio between the power of the river, as determined by its volume and fall, and the quantity and nature of falling rock, as determined by rock structure and by rate of regional uplift, must evidently be of large importance in such cases.

It is thus conceivable that such a river as the Colorado may have been prevented from developing meanders in certain stretches of its canyons by the overwhelming descent of landslides whenever and wherever the river attempted to enlarge a turn to one side or the other; for landslides ought to be most plentiful just where the river undercuts the canyon walls. The vigorous forward growth of boulder deltas from side canyons might contribute to the same result, for they form narrows in the river. Yet some of the upper canyons of the Colorado are mapped in very sinuous courses, and in such canyons rock-falls from the undercut amphitheater walls have evidently not prevented the river from developing its meanders and widening its meander belt. Possibly, as above suggested, the nature of the rock in the canyon walls,

and the degree to which it is shattered when it falls into the river may have something to do with the meandering habit of the river in some canyons and its nearly rectilinear habit in others. Certain it is that the cross-bedded sandstones of the White cliffs in southern Utah have very little talus at their base; while other sandstones of that region supply a heavy talus of large blocks. Powell's account of Labyrinth canyon, where the river "nearly doubles on itself many times" (Exploration of the Colorado River of the West, 1875, 52), does not give details as to the nature or amount of talus at the base of the undercut amphitheaters, but states that the canyon "is cut through a homogenous sandstone" (170), which I take to be of the same age as the sandstones of the White cliffs. Where this homogenous sandstone is actively sapped by the retreat of the weak underlying beds beneath the south-facing cliffs of the great cuesta through which the canyon is cut, "huge blocks . . . have fallen from the upper part of the escarpment" (173); whether such blocks occur in the canyon, where the weak underlying beds have dipped northward beneath the river, is not stated.

In a more mature stage, the irregular formation of a sand-bar in the channel, especially in the tangent between two meanders, may split the current and cause a new curve to be begun by the larger part of the stream. This process has been described by E. F. Fisher, who calls it the partition process (Proc. Boston Soc. Nat. Hist., xxxiii, 1906, 16—).

Relation of River Volume to Meander Radius.—The most important point, however, to be here noted is the different effect of an accident of given strength on rivers of different size. A large river will be utterly indifferent to an accident which will easily suffice to turn a small stream from its course. A small stream may be thrown into new contortions by a sod-slip, but the Mississippi takes no notice of caving banks, even when they carry large trees into its vast flood. It is this capacity of trifling accidents to produce new curves in the course of little streams, already somewhat sinuous because of the development of small curves from small initial bends and turns, that explains why such streams run in small, close-set meanders, which, being close-set, must be cut off before they grow large; and it is the indifference of great rivers to small accidents, as well as to small initial turns and bends, that allows them to select only the wide-spaced bends and turns for development into large meanders, which, being wide-spaced must grow still larger before they can be cut off under the action of a river so great that little accidents do not affect it. However few and simple the initial bends of a little stream, it must soon develop many new curves because of the many small accidents that will deflect it—unless indeed, as suggested above, the accidents are

so serious and so plentifully and impartially distributed along both sides of its course, as to prevent the growth of curves instead of promoting them. However small and numerous the initial bends of a great river, and however abundant the trifling accidents that later happen along its course, it will overcome all these small affairs, and pay heed only to the larger ones.

Incised Meanders of Revived Rivers.—When a river, which has already established a meandering habit on the open floor of a mature or old valley, is impelled to renewed vertical erosion by regional uplift, the conditions analyzed above for a young river again find application; but in the present case the revived river begins the incision of its valley in the new cycle with a system of meanders already developed, instead of with the irregular bends and turns of a new young river. The incised course of a river, revived from a previous maturity or old age, should therefore exhibit many regular curves with more systematically carved amphitheaters and better trimmed or sharpened spurs, than those of its first youth. Jefferson states in the article cited above that the meander belt of incised rivers in meandering valleys averages 30 times the river width; on open floodplains this ratio is 18. Ramsay was one of the first to draw attention to incised meandering valleys, two of the examples that he adduced being the Wye in England and the lower Seine in France (Phys. Geol. Geogr. of Great Britain, 1874, 242). It does not, however, seem to be necessary always to assume that meandering valleys require two cycles of erosion for their development; for a meandering course may be assumed during the gradual incision of a first cycle valley as Winslow showed (Science, xxiii, 1893, 31), and as has here been explained in an earlier paragraph; and curiously enough it does not always seem to be the case that the revival of a mature or old, and hence presumably meandering river will result in producing a meandering valley; for some uplifted peneplains are trenched by comparatively straight valleys, although the rivers of a peneplain before uplift ought, from all that we can infer of old rivers, to have had a meandering habit. It may be here pointed out that the presence of a cover of unconsolidated deposits on a peneplain, as an aid in the development of meanders to be afterwards incised in the underlying rocks as the result of regional uplift, does not appear to be necessary; rivers on a peneplain must, before its uplift, be in their extreme old age, and old rivers ought to be of meandering habit. No special conditions need therefore be postulated to account for the perfectly expectable occurrence of an incised meandering valley in an uplifted peneplain; it is the absence of meanders in young or submature valleys incised in uplifted peneplains that demands special explanation: no satisfactory explanation of their absence has yet been given. Increase of

velocity as a result of uplift, to which some authors appeal as a means of rectifying a river, should rather increase its sinuosity.

The smaller the ratio of depth of valley incision in an uplifted peneplain to radius of river meanders, the more distinctly will the new valley, as well as the river at its bottom, meander in the youthful and submature stages of the new cycle. Hence incised meandering valleys—that is, valleys limited by meandering margins of the uplands, right and left, beneath which they are entrenched—are best seen where large rivers, revived from an advanced stage of development, have cut new courses in moderately uplifted peneplains. If the depth of incision is great and the meander radius is small, the valley, as defined by the top of its walls, will not meander to any significant degree, although the stream at its bottom may be very sinuous. Furthermore, the course of a river in a well-developed incised meandering valley must not be conceived as having been cut down vertically beneath the course that it had before its revived erosion began; for during its new cycle of work, its meanders must have expanded in radius and arc and its whole system of curves must have been pushed down valley. The reconstruction of the former river course in a meander belt of less width and with curves farther up-valley, may be attempted by connecting the contours of the slip-off slopes on successive spurs, right and left. This problem is discussed in one of my earlier papers on " Incised Meandering Valleys " (Bull. Geogr. Soc. Phila., iv, 1906).

Underfit Rivers in Incised Meandering Valleys.—We may now enter upon the more special subject of this paper. The best cases of underfit rivers are found in well-defined incised meandering valleys, the floors of which have a breadth sufficient to allow the river to wander in a more irregular path than that of the curved valley. The valley must therefore be further developed than in its youth, when no floodplain has been formed, and not so far as in its old age, when all definition of meandering course has vanished; that is, the valley must be in its maturity. The underfit rivers of such valleys wander aimlessly in small curves in the regularly meandering larger curves of the valley floor, instead of systematically following the base of the amphitheater walls and of the undercut spur slopes, and thus normally continuing the former widening of the valley floor. They now touch or abandon the valley sides anywhere or nowhere in the most arbitrary and haphazard fashion. A number of examples of this kind will be presented farther on.

Underfit Rivers and River Floods.—Some geographers who do not regard an underfit river as indicating a secular diminution of river volume, explain the larger curves of the valley by the action of the river when in flood. This has never seemed to me a successful explanation. If the pattern of a meandering valley is due to the work

of its river when in flood, the river channel should systematically follow the base of the undercut slopes, and the river at low water would have to get along as well as possible in such a channel. Such is the case in certain meandering valleys that I have seen in the subarid plains of North Dakota, where the variation from flood to low-water stage is strong; but even at low water the streams of such valleys would not be called underfit, in the sense here given to that term. The only conditions under which a low-water channel could depart in underfit fashion from the base of the undercut walls in a meandering valley that owes its large curves to the work of flood waters, would be in a region where floods came so rarely that the low-water stream, gradually aggrading and wandering away from the flood channel, could develop an underfit course for itself during the long intervening dry weather periods; and even in such regions, the low-water streams would, for a certain time after a flood, follow the fit course of its deep channel.* The special conditions of long droughts and rare floods do not obtain in valleys where underfit rivers are observed: the river floods there spread inefficiently—as far as the pattern of the valley is concerned—over the valley floor; they doubtless modify the course and the curvature of the underfit low-water channel, but they do not transfer it to the base of the undercut slopes; yet along the base of those slopes a river must have run when the systematic features of the valley were developed. Of course, so long as the features which are here described as systematic—namely, the steep walls of the amphitheaters, the alternating spurs of trimmed, sharpened or blunted forms, and the associated narrow or broad floodplain scrolls fitted in orderly fashion around the ends and along the slip-off slopes of the spurs, right and left, down the river course—are looked upon as arbitrary or accidental, the haphazard departure of an underfit river from the base of the undercut slopes would not excite wonder or call for inquiry. It was therefore for the purpose of explaining and establishing with some detail the origin of the normal forms seen in an incised meandering valley that the earlier pages of this article were written; for only when one is convinced that such valleys really do exhibit normal forms, and that such forms can be developed only by the systematic action of a fit river, working competently in curves of the same dimension as those of its valley, will the irregular course of underfit rivers excite surprise and demand investigation.

* A case of this kind is reported by S. S. Visher, in "An Example of Storm Erosion in the Badlands" of South Dakota (Journal of Geography, xi, 1913, 294-296). A violent flood swept away the smaller trees of a canyon floor, thus showing that the flood was an exceptional and not an annual occurrence. "Where formerly the stream had been winding, it was now straightened"; hence the winding of the former stream, a small one which "trickled the full length of the canyon," must have been self-developed since some previous master flood.

River Capture and Underfit Rivers.—Let a branch, AB, Figure 1, of one mature river, CD, capture and divert the upper waters, EA, of another mature river, EF; then the lower or beheaded portion, AF, of the second river, being necessarily diminished in volume by the loss of its upper waters, must aggrade its valley floor; and as soon as its former channel is thus obliterated, the beheaded river ought to develop an underfit relation to its previously carved valley-curves, in the sense of meandering irregularly on the aggraded floor in curves of a smaller pattern. Conversely, the capturing branch, AB, and its river, BD,

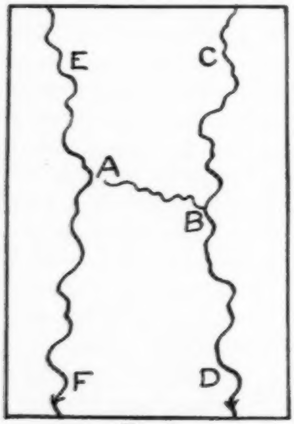

Fig. 1.

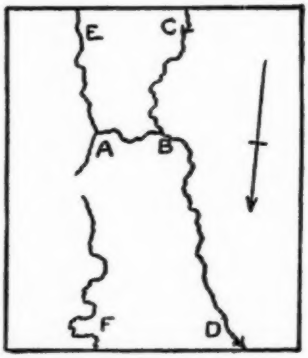

Fig. 2.

below the entrance of the capturing branch, being increased in volume, should exhibit for a time an overfit relation to their valley curves, in the sense of actively enlarging them: this will be particularly evident for a moderate distance below the elbow of capture, where volume is increased in largest proportion. The upper waters, EA and CB, of both rivers should still fit the curves of their valleys, but the diverted upper waters, EA, should, while establishing a new graded slope, incise their course beneath the former valley floor upstream from the elbow of capture, as if revived by uplift; such streams may be described as revived by capture.

In a good number of observed examples, some of these deduced changes are verified and others are not. In case of the Aisne-Aire in northern France, simplified in Figure 2, the Aire, EA, was captured by a branch, AB, of the Aisne, CD,—the Aire being thus transferred from the system of the Meuse to that of the Seine—here the beheaded lower course, AF, of the former Aire, known as the Bar, offers a very striking example of underfit behavior; it was indeed this example, as shown on a sheet of the excellent Etat-major map (1:80,000) of

France—reproduced in my Geographical Essays (p. 610)—that first drew attention to this subject some twenty years ago. But the Aisne below as well as above the point, B, where the diverted Aire, EAB, joins it, is also underfit, though to a less degree than the Bar. Again in the long known example of the diversion of the upper Moselle, MN, Figure 3, to the lower Moselle, NO, from its former path, NP, as a tributary of the Meuse, RQ, the Meuse is conspicuously underfit in its upper course, RP, above the former entrance of the upper Moselle as well as below, PQ. Evidently, then, some other cause than

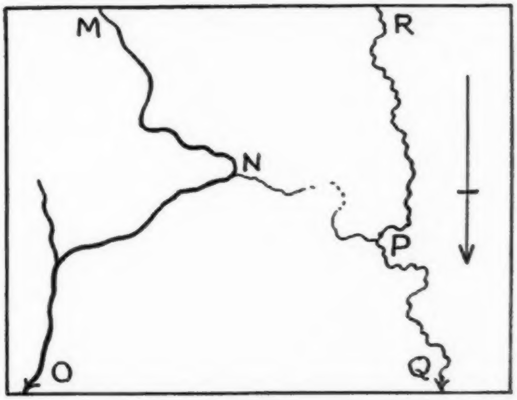

FIG. 3.

loss of volume by capture must have operated in these two cases. Yet a study of the headwaters of the Aisne and of the Meuse, as represented on the French maps, fails to reveal any recent loss by capture. Various other underfit rivers are also known, in which no signs of loss by capture are found.

CLIMATIC CHANGE AND UNDERFIT RIVERS.—If rivers were made underfit by a change from greater to less rainfall, all the rivers of a large region, so far as their valleys are appropriately mature, ought to become underfit, because a climatic change of this kind cannot be regarded as locally limited to certain river valleys. As a matter of fact, certain rivers remain competent to follow their valley curves in regions where others have become incompetent or underfit.

A possible cause of diminished run-off, resulting in an underfit river habit, may be found in increased evaporation as a result of clearing and cultivating an originally forested region; but no definite conclusion has been reached in this direction.

LEHMANN'S EXPLANATION OF UNDERFIT RIVERS.—The peculiar merit of Lehmann's explanation of underfit rivers lies in the normal and spon-

taneous operation of the processes which it invokes; and these processes are moreover so simple and expectable that the underfit habit of rivers in maturely incised meandering valleys might have been definitely deduced and predicted years ago as an ordinary, normal occurrence, had geographers developed the use of deduction along with observation as fully as astronomers have.

Loss of Surface Flow to Deep Percolation.—When a new land surface is offered to the action of rain and rivers, or when a land surface already normally advanced to its maturity or old age is uplifted so that a new cycle of deeper erosion is introduced, some of the surface water penetrates underground and finds its way for a less or greater distance through fissures and other minute passages in the underlying rocks. Although the percolation of water through such passages is slow, its long continued action may gradually open the passages and facilitate underground movement, whereupon the proportion of percolating underground water to flowing surface water will increase. In limestone districts the underground passages, enlarged rapidly by solution, may in time dispose of all the rainfall that is not evaporated, and surface streams in such districts will then disappear. In other kinds of rocks, less subject to removal by solution, the variation in the proportion of surface flow to underground percolation during the progress of a cycle of normal erosion is not yet known, but it seems reasonable to suppose that underground percolation may increase from youth to late maturity. In old age, however, although underground passages may be then well opened, the reduction of the general land surface to low relief will diminish the "head" of pressure to which the slow movement of underground waters is due; hence, through this late stage of the cycle, even though a good volume of water may then be stored in the underground passages, its movement may be so slow that the surface waters will regain the large proportion of run-off to rainfall that they had in youth—except that loss by evaporation from the slow discharge of the run-off in old age may be large. If such a restoration of volume occur, we should not expect to see it accompanied by a return to a fit or competent relation of river to valley; for in old age the valleys will have lost all their mature definition by the wasting away of their sides; the rivers will then wander freely over broad floodplains, and however far the lost river volume is regained, the terms, fit, underfit and overfit, will find no application.

Loss of Surface Flow to Shallow Underflow.—In addition to loss of surface water to deep underground percolation, there is a loss to shallow underflow, as soon as the accumulation of alluvium on the valley floor in maturity allows some water to creep slowly along at a small depth beneath the floodplain surface. This loss is relatively negligible in the early youth of rivers which are working in firm

rocks, for the bed and banks of their channels will be rock-bound and almost free from alluvium. But when the graded condition of maturity is reached and the river continues its lateral erosion without further valley deepening, the widening floodplain then developing on the mature valley floor will consist of alluvium about as deep as the river at time of flood. The lower part of the alluvium, lying unconformably on bed rock, will consist for the most part of the largest cobbles and coarsest gravels that the flooded river can sweep along; for these coarse materials are the first to be laid down on the bed of the temporarily deepened flood-channel as the high waters begin to subside. The upper layers of the alluvium, on the other hand, will consist of sands and silts which the laterally shifting river lays down on the inside of its meanders, or which the slowly subsiding overflow waters strew over the floodplain. With the first formation of such deposits, that is, with the first development of narrow floodplain scrolls as the valley passes from youth to maturity, a loss of surface flow to underflow must begin; with further widening of the flood-plain scrolls the loss of surface water to underflow must increase; and from the beginning of this loss a curious series of reactions is set in operation, whereby the loss of surface waters is still further augmented; but with the approach of old age and diminution of "head," the underflow, although holding a considerable volume of water, presumably becomes so sluggish that the surface may again, as in youth, dispose of nearly all the run-off. The reactions just mentioned must be further considered.

While a young river is still deepening its valley, its alluvial deposits will occur only in small and disconnected channel-pockets, and the underflow that locally passes through them may be neglected. When the river is just attaining the graded condition, its carrying power is already diminished below the measure previously possessed, because the impetuous current of steep-channelled youth is now reduced to the temperate current of graded maturity. The diminution of carrying power, however, should not be inferred directly from the diminution of velocity, still less from the sixth power of the diminution, for the tempered current of maturity has a larger cross-section than the impetuous current of youth, and hence the loss of velocity is partly made up by increase in the amount of water present. Furthermore, the proportion of breadth to depth is greater in a mature than in a young river channel, and the increase in the number of threads of current running on the widened channel bed, where a large part of river transportation is effected, still further counteracts the effect of diminished velocity. But during these changes, the load of detritus to be carried is increasing, because the progressive dissection of the general land surface, characteristic of the advance of a normal cycle of erosion,

involves an expansion in the area of the valley-side slopes, from which the greater part of the detrital load of mature streams is supplied. Consequently, the decrease of over-abundant youthful carrying power and the increase of scanty youthful load will bring these two variable quantities to the balance that characterizes the graded condition of maturity. It by no means follows, however, that the maturity of the general land-surface, as measured by maximum dissection with maximum relief, is reached at the same time as the maturity of the larger rivers. Maturity of land-surface dissection is, in regions of moderate altitude, reached after, perhaps long after a mature grade is established in the main rivers. Therefore the load of such rivers will continue to increase even after graded courses are developed and after loss of surface water to underflow is well begun; and a result of this continued increase of load must be an aggradation of the already graded valley bottom, and a still further loss of surface flow to underflow in the thickened alluvium. The theoretical cause of aggradation of a mature valley floor was deduced a number of years ago; but the accompanying loss of surface water to underflow was then entirely overlooked.

Varying Equilibrium of a Graded River.—As a result of these various modifications, it appears that the variable quantities here involved in delicate interactions are continually falling out of one equilibrium and into another; but as the changes in their values are mere differentials of the values themselves, the changing equilibrium seems to us, in our brief period of observation, unchanging. As load increases, a part of the increase will be strewn along the floodplain, whereby the slope is raised, the velocity of the river is accelerated, and its carrying power increased sufficiently to sweep along the remainder of the load. As the floodplain is in this way given greater and greater depth, the surface flow is further reduced by loss to underflow, the carrying power is thereupon still more diminished, and still more of the load must be laid down; and so on, continuously. Hence, if no counterbalancing factors entered the problem, it would seem as if the floodplain ought to rise higher and higher and fill a greater and greater depth of the mature valley. But the variables here considered do not suffer large changes of value; the resulting readjustments of floodplain slope to carrying power and load are of small measure; and eventually certain counterbalancing factors must arise, particularly as the stronger relief of maturity weakens into the fading relief of old age; and no great depth of spontaneous aggradation in the mature valley need be expected.

Regain of Surface Flow in Old Age.—A very small counterbalancing factor may be found in the encroachment of the aggrading floodplain on the side slopes of the main valley, from which some of the

river load is supplied; but this is a second differential of the quantities of the first order, such as carrying power and load, and need not be considered in an equation where many stronger factors are of uncertain value. Two much more important counterbalancing factors, and indeed very effective ones, are found, first in the decrease in the quantity of load and in the refinement of its texture as the higher hills of maturity are worn down into the lower and lower hills of old age, and second in the accompanying decrease of "head" whereby underflow becomes sluggish and withdrawal from surface flow to underflow is checked. Thus an ageing river is given lighter and easier work to do, and has a larger and larger volume with which to do it—provided that regain of surface flow is not overcome by diminution of rainfall and increase of evaporation due to decrease of relief. The old river should therefore slowly wear down the aggraded floodplain of late maturity to a fainter slope and a less depth; and with diminution of depth the floodplain will hold less underflow. But however all this may be, these transcendental questions need not be pursued farther; they have already been carried beyond the need of the special inquiry here undertaken.

Underfit Rivers and Underground Waters.—If we now return to the examples of captured rivers given above, it becomes possible easily to explain the underfit meanders that they unexpectedly present by ascribing the loss of volume there implied to increase of deep percolation and of underflow in the widening and probably thickening alluvium of their aggraded valley floors. The Marne, a large branch of the Seine system, shows a moderately underfit habit of flow not far east of Paris; and it was for this river that Lehmann in the spring of 1912 offered his ingenious explanation; truly a far better explanation than any other yet proposed. More than that it may not be wise to say at present. Studies of underlying rocks and measurements of depth of alluvium along with estimates of volume of percolation and underflow in proportion to surface flow should be made in many cases of underfit rivers before a problem so complicated as this can be regarded as settled. But in the mean time it may be permissible to regard underfit rivers as, so far as they are concerned, confirming rather than contradicting the consequences that may be now deduced from the theory of the normal cycle of erosion.

Terminology of Meandering Valleys and Underfit Rivers.—Those who more or less fully accept the foregoing explanations for underfit rivers in incised meandering valleys will naturally wish to describe actual occurrences of such features in terms suggestive of their development. A general terminology for incised meandering valleys has been already indicated, in relation to successive stages of the cycle of erosion in which they are developed. Elongated and opened amphi-

theaters, undercut and slip-off spur-slopes, trimmed, sharpened and blunted spurs, and narrow and wide flood-plain scrolls are, as already suggested, helpful phrases. A fuller terminology is still needed to express the various patterns and dimensions of meanders, with respect to length of arc and radius of curvature. Open, half-turn, and dove-tail meanders are illustrated in Figure 4, in examining which it should be remembered that river diagrams are always simpler than rivers. Radius of curvature can be most definitely expressed in feet or miles,

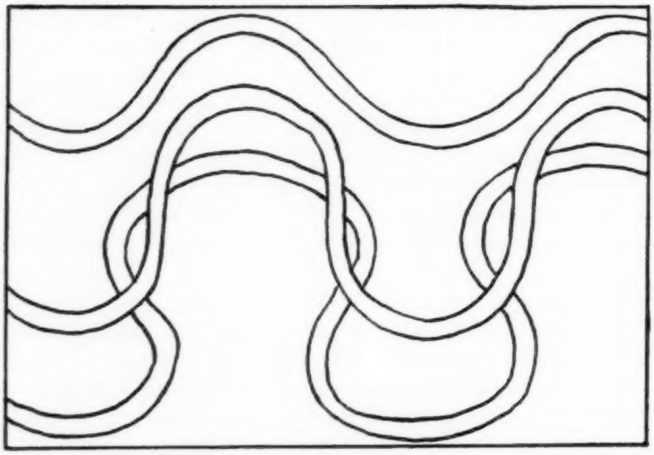

FIG. 4.

because such terms as short and long have no established meaning in this connection. The same is true regarding depth of valley incision and breadth of meander belt.

In describing underfit rivers in incised meandering valleys, the pattern and size of their meanders should be first stated in such terms as have been just proposed. Then the degree of their underfitness should be indicated by adjectives such as slight, moderate, striking and extreme, corresponding to the four underfit lines in Figure 5. The open meandering course of the upland river, before the incised valley as here drawn, was excavated is shown by pairs of broken lines drawn across the top of the axial slope of each spur at the upland level. The valley having been excavated, a slightly underfit river is shown by two parallel lines which fail by small amount to fit the smooth meanders of the valley; a moderately underfit river, by a single dotted line; a strikingly underfit stream by a broken line that meanders right and left on the meandering valley floor; an extremely underfit stream by a full line of minute crenulations. The lower Seine in Normandy shows a slight underfitness; the Meuse in northeastern France is an example of a moderately underfit river, and the Bar,

one of its beheaded tributaries, may be taken as the type of an extremely underfit stream. Stretches of both of these rivers, as shown on the Etat-major map of France, are reproduced in my Geographical Essays (pp. 595, 610). The term, underfit, will itself convey an explanatory suggestion to those who recognize that it is the sign of a peculiar relation of river and valley, whether they fully accept any explanation

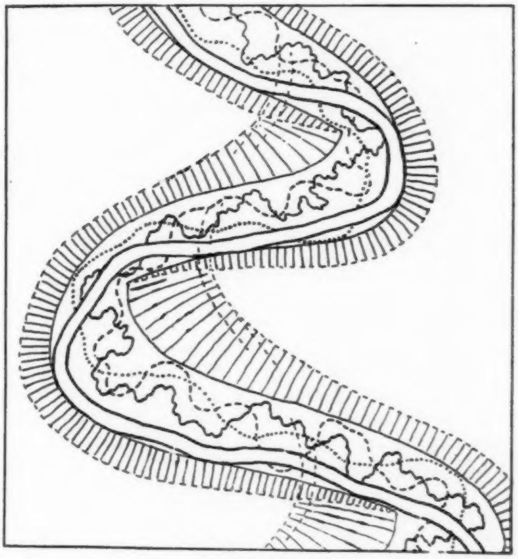

Fig. 5.

for the implied diminution of the river or not. When it is qualified, as slightly, moderately, strikingly or extremely, the explanatory suggestion of something peculiar is still more evident.

The Larger Lesson of this Problem.—There is a curious tendency on the part of certain conservative geographers to discredit the use of deduction in the treatment of geographical problems. Truly if deduction were the only mental faculty employed by a geographer, his results would be highly fanciful; but it argues a strange lack of imagination in the mind of a conservative for him to suppose so abundant a supply of imagination in the minds of other geographers, particularly of those who are concerned with the study of the solid land, that they fly off into the open space of pure deduction and abandon the safe footing of direct observation. Deduction is of no value in a subject like geography unless it is applied chiefly, perhaps exclusively, to drawing forth the consequences of a theory that has been invented to account for the inductively generalized facts of observation; and the deduced consequences of a theory have little value, except as they

lead one on to renewed observation, whereby the correctness of the deductions, and therewith the correctness of the theory from which they are deduced, may be tested. Those who suppose deduction to be otherwise used in geography thereby either disown or discredit their own methods of work. But all this is no novelty as a matter of principle, although it would seem, if one is to judge by the comments of certain writers, to be a novelty in their practice. Playfair made it all clear enough over a century ago, when he wrote as follows:

"The truth, indeed, is, that in physical inquiries, the work of theory and observation must go hand in hand, and ought to be carried on at the same time, more especially if the matter is very complicated, for there the clue of theory is necessary to direct the observer. Though a man may begin to observe without an hypothesis, he cannot continue long without seeing some general conclusion arise; and to this nascent theory it is his business to attend, because, by seeking either to verify or to disprove it, he is led to new experiments or new observations. He is also led to the very experiments and observations that are of the greatest importance, namely, to those *instantiæ crucis*, which are the *criteria* that naturally present themselves for the trial of every hypothesis. He is conducted to the places where the transitions of nature are most perceptible, and where the absence of former, or the presence of new circumstances, excludes the action of imaginary causes. By this correction of his first opinion, a new approximation is made to the truth; and by the repetition of the same process, certainty is finally obtained. Thus theory and observation mutually assist one another; and the spirit of system, against which there are so many and such just complaints, appears, nevertheless, as the animating principle of inductive investigation. The business of sound philosophy is not to extinguish this spirit, but to restrain and direct its efforts" (Illustrations of the Huttonian Theory, Edinburgh, 1802, pp. 524, 525).

The larger lesson of Lehmann's explanation for underfit rivers is that deduction ought to be more consciously and more thoroughly used in geographical investigation than it yet has been. The same larger lesson should be learned from the explanation of hanging lateral valleys over main valleys by means of glacial erosion. This explanation, foreshadowed by La Noë and De Margerie from evidence in the Alps (1888) and stated explicitly by Gannett (1898) in presence of the deep glacial trough of Lake Chelan, might have been deduced from established principles before any such trough was seen, inasmuch as Playfair had nearly a hundred years earlier pointed out the normal relation of branch and main valleys of ordinary erosion, and as every field geographer must have long been familiar with the relation of the beds of branch streams to those of main streams; the delay in the solution of the problem of glacial erosion was therefore largely due to the fact that no one had entered it with a conscious determination to study its deductive side as fully as its observational side. The larger lesson should again be learned from the explanation given by Wallace (1893) for the bayless lakes that so often occupy glaciated mountain valleys, the origin of which had been in debate between Ramsay and Lyell 30 years before; for Wallace's explanation, which accounts for such

lakes not by the warping but by the glacial overdeepening of preexistent normal valleys, might have been much earlier deduced in view of Dana's principle (1849) that coastal embayments must result from the partial submergence of a dissected land surface. And if errors are sometimes made in studies where deduction has had a part, as appears to be the case in the interpretation of the New England upland as an uplifted and maturely dissected peneplain, in the shaping of which marine abrasion was thought to have played no part, the evident lesson of such a mistake is, not that the effort to explain the origin of the uplands should not have been made, but that it should have been made more carefully, and that all of its observed and deduced elements should have been more closely scrutinized.

But in one sense, this exhortation is unnecessary; for it is perfectly clear that the geographers of the coming generation will give an increasing share of attention to the deductive side of their problems. A year's review of current geographical literature makes that evident.

Application of Lehmann's Principle to Regional Geography. —The object of physical geography is not to explain the past action of the processes by which the present state of the earth's surface has been brought about, but to describe the present state of the earth's surface in the best possible manner. It is, however, becoming increasingly common to attempt to describe the earth's present features by explaining their origin; that is by giving their history. Unfortunately this method of description frequently involves the discussion of so many conditions and processes of a former time, that the attention of both writer and reader is distracted by them from the present to the past, and writer and reader are to that measure metamorphosed from geographers into geologists. Some method of description should be invented whereby the geographical student, while still enjoying the vivifying influence that comes from an understanding of the origin of existing features, shall not have his attention seriously distracted from geographical to geological matters.

The best method yet found of securing this desirable end is to generalize and systematize the analytical explanation of present features through past processes. Instead of limiting an explanation to a single example of a general case, the explanation should be extended to cover all the phases of the case in their natural or evolutionary sequence; and then as an aid in gaining familiar acquaintance with all these phases in systematic order, appropriate names, usually in the form of nouns with qualifying adjectives, should be given to the type-concepts deduced for a certain number of stages in the sequence, so that the mere mention of a name will immediately and easily bring to mind the concept of all the detailed features that the name covers in their rationally developed and systematically associated relations. So long as the processes involved in an explanatory treatment remain

unfamiliar, and so long as the evolutionary sequence of the resulting features remains uncertain or obscure, the student cannot give his chief attention to the explained features, but must be distracted by trying to understand the explanation of the features. On the other hand, as soon as the explanatory treatment of a problem of this sort becomes clear, the deduced succession of evolved features and their proposed names will be easily apprehended and remembered; and thereafter the mere mention of a name will suffice to call up the corresponding type-concept and its meaning. Thus an explanatory description of an earth-feature, however many past conditions and processes it may involve, becomes a properly geographical description because it holds our attention closely to the present.

It is the principle of systematized explanation here involved that justifies the long and somewhat detailed treatment given above to the problem of meandering valleys and underfit rivers, as a practical aid in regional geography. For it is evident that the larger the mental equipment of a geographer, the better he can observe; and the enlargement of mental equipment is in no way more easily accomplished than by the careful and systematic deduction of mental types from theories that have been well established by thorough analytical investigation based on abundant observation.

The easy and effective use of an explanatory term in the geographical description of an underfit river in an incised meandering valley therefore involves not simply the explanation of the single case that the observer wishes to describe, but the thorough-going analysis of all the forms of the class to which the single observed case belongs, and then the establishment of a systematic series of type-concepts representing all these forms, and the adoption of appropriate names for a sufficient number of them, in the order of their evolutionary development. It is only after these two steps, the first analytic, the second systematic, have been carefully taken that an explanatory description can be used to best advantage. Evidently, if an observer who makes use of such a description is to be understood by his colleagues who have not seen what he has, he and they must have had the same training and must use the same terminology.

There is therefore a double responsibility, resting on geographical readers and writers alike, to analyze geographical problems and to systematize the results of analysis, as the essential means of making the best use of explanatory descriptions of geographical objects in regional studies. Many other problems offer as good, but no other problem offers a better opportunity for practice in this helpful preparation for the thorough treatment of regional geography than is found in the application of Lehmann's principle to the explanatory description of underfit rivers in incised meandering valleys.

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THE SIGNIFICANCE OF EVAPORATION IN ANIMAL GEOGRAPHY

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INTRODUCTION.—The geographic importance of an environmental factor is determined by its influence upon organisms. Environmental factors influence animal organisms in one of three ways. (a) *They may produce death.* (b) *They may modify structure or behavior.* (c) *They may stimulate migrating animals and cause them to turn back when an increase or decrease in the factor is encountered.* It has been demonstrated again and again that various isolated factors such as temperature, light, moisture, dryness, etc., may influence organisms in any or all of these three ways. Likewise it has been shown that various unanalyzed combinations of these factors produce death. Certain animals are killed by high temperature, intense light, much moisture, dryness, etc. The factors have been repeatedly shown to modify form, color, size and behavior of animals under experimental conditions. Further, it is well known that nearly all animals turn back upon encountering too high or too low temperatures or too weak or too strong light, as well as many other factors. Thus we may consider that a very large number of factors are known to affect organisms and to be of significance in animal geography.

The Influence of Environmental Factors.—Climatic conditions are so complex that animal and plant geographers have long sought some measurable index of climatic conditions. A few authors have held that food is a most important index. Others that moisture is the

controlling factor. Merriam has worked for many years on the assumption that total temperature above an arbitrary minimum, during the growing season, is the best index of the control climatic factors exert upon distribution.

The Importance of Evaporation.—It is the purpose of this paper to point out a large body of experimental work which shows conclusively that evaporation is the best index of conditions affecting warm blooded animals. A review of some experimental work by the writer, pointing to the same conclusion concerning cold blooded animals will also be presented.

The three ways (killing, modifying, producing avoiding reactions) in which the environment may influence organisms are not to be regarded as independent of one another or essentially different, because all result from interference with the internal life mechanism. The different results are dependent upon the character of the life mechanism in question and upon the intensity of the stimulation. Take as an example the effect of evaporation. Undoubtedly the same disturbance which causes the animals to turn back upon encountering air of high evaporating power results in death if it is continued and intensified. There is great difference in the time required to kill different animals from the same habitat, by evaporation and by other conditions, which indicates that distribution is far less a life and death matter than is commonly assumed. Reactions to conditions in experiment, the conditions selected and avoided, indicate the conditions suitable for the animals in nature. If such tests are made with reference to a sufficient number and combinations of conditions and at a number of periods in the life history, the reasons for the presence of animals in their environments may be expressed in terms of measured physical factors selected and avoided. These measures of the physical factors have almost invariably been found to represent the geographic conditions in the animal's environment. Tests of the reactions of animals, do not, to be sure, indicate everything that can be determined in the matter of relation to geographic conditions but there is little doubt that the particular type of reaction which results in turning back maintains animals in their usual environments wherever these end abruptly. Thus generally speaking, forest animals are probably restricted to forests, marine fishes are kept out of rivers, etc., by their activities merely because they turn back when the change in conditions is encountered. A large amount of data has been accumulated by students of animal behavior in the past few years, which shows that this works with a niceness of detail which is sufficient to support the view that animals are distributed very largely with reference to their behavior reactions. There are however doubtless cases in which this does not apply and where failure to survive

during some critical period, as for example during the egg stage, or the earliest stages outside of the egg, may be the cause of the absence of a species in question. But even here the results can rarely be ascribed to a single factor. It is likewise clear that the foundation for the explanation of distribution must be sought in experimental study of the effect of factors and combinations of factors upon organisms. Thus modern animal geography becomes *physiological animal geography* (Shelford '11).

Further as a result of selection of habitat or rather failure to leave the usual habitat and elimination of unadapted animals at sensitive periods, we may expect to find general physiological agreement among animals living habitually in similar geographic conditions. The writer has performed a series of experiments to determine the correctness of this general conclusion and the best means of measuring climatic conditions from the standpoint of modern animal geography.

Experimental Results with Evaporation and the Importance of Experimental Work to Animal Geography—*Methods Employed in Experiments.*—A series of experiments was performed by the writer (Shelford, '13) on frogs, salamanders, millipedes, spiders, insects. They were studied in glass tubes through which air of different evaporating powers was passed until the animals died. The reactions were tested in long narrow cages in which the rate of evaporation was different in the two ends and in the center. These different rates were produced by forcing air across the different thirds of the cage, moist air across one end third, ordinary air across the middle third, and dry, warm, or rapidly moving air across the remaining third. The rate of evaporation was measured by passing the air over Livingston porous cup atmometers at the same rate as across the cage. The behavior of the animals in the experimental cage was studied and compared with their behavior in an identical control cage which contained still air. The animals sometimes turned round in the control cage when no difference in the condition of the air existed, but on the average they turned back as often when headed in one direction as when headed in another. In the cages in which differences in evaporation were maintained they turned back much more often when headed toward one kind of air than when headed toward another. As a result, more time was spent in one half than in the other. If, for example, 70% of the time was spent in moist air, the animals often turned back 90% of the total turnings from the dry air. Thus the animals were negative to dry air and if we subtract the percentage of positiveness, namely 30% and 10% respectively, we have 40% and 80% respectively, which gives an average of 60% negative to dry air. This is the mode of determining the ratings given in Table I. The ratings represent negativeness or positiveness of reaction after the trials of

the opposite sign have been subtracted. Table I gives the rating of the species studied, obtained in this manner.

TABLE I.

Showing the rating of the different species studied when the turnings back from the modified air and per cent of time in the two halves of the experimental cages are regarded as of equal value. The ratings were obtained from the per cent of total turnings from the halves and from the per cent of time in the halves. The differences between the two per cents in each case were added and divided by 2. When the greatest number of turnings was from the end in which least time was spent the turnings and time are of the same sign (+ or —). Thus, the rating represents the degree of positiveness after the negative trials have been subtracted and vice versa.

Species	Controls		Experiments: Evap. Produced by						Average	
			Dryness		Movement		Temperature			
	Number.	Rating.	No. Expts.	Rating.	No. Expts.	Rating.	No. Expts.	Rating.	No. Expts.	Rating.
From Beech woods:										
Red-backed salamander (*Plethodon cinereus*)	10	± 3.0	5	—71	2	—66	2	—82	9	—73
Sticky salamander (*Plethodon glutinosus*)	2	± 7.0	1	—88	1	—82	..	.....	2	—85
Ground beetle (*Pterostichus*)	1	±11.0	1	—72	..	.....	..	.....	1	—72
Wood frog (*Rana sylvatica*)	19	± 1.5	5	—68	2	—80	2	—69	9	—72
From Oak and Beech woods:										
Millipede (*Fontaria corrugate*)	10	± 6.0	6	—43	4	—55	2	—83	12	—60
Widely distributed (collected from sand dunes):										
Toad (*Bufo lentiginosa*)	9	± 8.0	4	—46	2	—23	3	—27	9	—32
From dry sand dunes:										
Digger wasp (*Microbembex*)	6	± 1.3	6	+ 6	..	.....	..	.....	6	+ 6
Spider (*Geolycosa* sp.)	7	±10.0	4	+18	2	+16	2	+12	8	+15

The Relation of Evaporation Effects to Integuments.—The animals killed by rapid evaporation fall into two distinct groups: (a) those dying with an evaporation varying from 0.07 to 5.40 c.c. after an exposure varying from five to one hundred and sixty-five minutes, and (b) those dying with an evaporation of 31.0 to 42.0 c.c. after an exposure of from 1,300 to 2,200 minutes. The first group was made up of soft-skinned amphibians, the second of chitin-covered Arthropods. Even though the Arthropods were much smaller and hence had more surface per volume (Hill, '06, p. 267), they lived from eight to four hundred and fifty times as long as the amphibians. In general, there was only a rough relation between survival time and reaction among animals *with similar integuments.* Of the amphib-

ians the red backed salamanders died in dry air in 58 min. and sticky salamanders in 87 min. They are rated respectively at — 72 and — 85; the toad died in 160 min. and is rated at — 32. Of the chitin-covered animals the ground beetle is rated at — 72 (single expt.) and died in 1,300 min.; the millipede at — 60, died in 1,830 min.; the spider rated at + 15, died in 2,200 min.

Evaporation and Habitat Groups.—The ratings given in Table I clearly fall into two groups which are habitat groups. The salamanders, millipedes and ground beetles (— 60 to — 85) were taken from the surface of the ground under the leaves in a primeval beech forest; the spiders and wasps (+ 6 to + 18) are regular residents of the driest open sand areas. The toad is an incidental resident of the sand area. A relation exists between habitat and survival time but it is confined to animals with similar integuments. No such relation exists when one entire habitat group is compared with the other habitat group. Omitting the toad we find that the regular breeding residents of the two habitats (beech woods and open dunes) differ in kind and degree of reaction in a manner comparable with the difference in physical conditions of the habitats (Shelford, '12b).

A further comparison of the different species given in the table shows important relations to vertical conditions of forest developmental stages (Yapp, '09; Sherff, '12; Shelford, '12a; Fuller, '12), evaporation being least in the ground and at the forest floor, increasing rapidly vertically. The wood-frog spends much of its time during the day hopping about the forest floor. The red-backed salamander lives more of the time beneath the leaves and is clearly more sensitive to evaporation. The sticky salamander occurs in numbers in the beech woods proper only in moist seasons. Ordinarily it is confined to ravines where Fuller ('12) found the average evaporation per day for the season to be 1.5 c.c. less than at the surface of the forest proper. Since the sticky salamander occurs in moister situations than does the red-backed the difference in the sensitiveness of the two species is related to habitat. The habits of the ground beetles are not well known; the species studied seem to be regular inhabitants of moist woods. The millipedes, while common in beech woods, are still more common in oak-hickory woods where evaporation is 1 c.c. per day greater. The millipedes are less sensitive to evaporation than the ground beetles. The reaction of the spiders and wasps is in accord with the high rate of evaporation in the sand dunes which they normally inhabit.

Summary of General Results—*The Experimental Results of the Writer.*—The animals studied reacted to differences in evaporation, whether they were produced by *movement, dryness* or *heat.* Forest (low evaporation) animals turn away from air of high evaporating

power, and show a preference for air of low evaporating power. Sand dune (high evaporation) animals turn away from moist air and show a slight preference for air of high evaporating power. Thus the *type of reaction is definitely related to the usual habitat of the animals.* Furthermore *all* the animals from a given habitat subjected to the tests, were found to be in *agreement* in reaction though there was *no general agreement* in the length of *time required to kill* them by desiccation.

Experimental Results of Other Investigators.—The work on the physiological effect of evaporation from the bodies of animals has been confined chiefly to the warm-blooded domestic animals and man. The loss of water from the human body was early noticed by Hippocrates and by Galen. Chalmers (1776), Seguin and Lavoisier (1789-90), Abernethy (1793), and Sharling ('42) all appear to have noted water output from the body or lungs. Tiedemann ('36) described the symptoms of great thirst experienced by travelers in the desert. The first thirst is followed by dryness and smarting of the throat; next the respiratory action is increased and later long deep breaths alternate with hiccoughs; hoarseness occurs and is followed by loss of speech; the pulse is quickened; the skin becomes dry; the muscles become weak and a feeling of great fatigue ensues with staggering and labored movements. The thirst then becomes maddening and loss of consciousness usually follows.

Some of the early experiments in physiology were water starvation experiments on birds and mammals. Nothwang ('92) summarizes this early literature. He states, on the basis of his own investigations, that fat animals resist lack of water better than those without fat. Weyrich ('62) studied the loss of water from the body and confirmed the work of earlier writers; Reinhard ('69) found that the water loss was dependent upon *temperature, humidity, wind velocity,* and *pressure.* These factors control evaporation (see also Falck, '72; Erismann, '75). Rubner ('90b, '90c) found that the rate of evaporation was of much importance in connection with the factors pointed out by Reinhard, in determining the rate of *metabolism,* and general heat *regulation economy* in men and dogs, and with Cramer ('94), noted the effect of hair covering and of sunlight upon water loss and heat regulation. Schierbeck ('93) carried on similar studies and (in '95) stated that evaporation should be measured.

Wolpert ('98, '99, '02a and '02b) studied the effect of moisture on laborers, the effect of oiling the skin on water loss, the influences of evaporation upon the skin, and the influence of air movement upon water loss and carbon dioxide production confirming the results of others and adding further details. Up to 25° C., CO_2 production is increased by air movements; at higher temperatures, decreased. Hal-

dane ('05) worked upon the effect of high temperatures on man and found that the discomfort was due to a *rise of body temperature.* The ill-effects were partially prevented if the air was kept moving, thus increasing the evaporation.

Hill ('06) summarizes the important work on the subject of water relations and heat regulation and adds the results of his own investigations. The heat regulating power of a mouse fails at 24°-25° C. (p. 269) in a saturated atmosphere, due to rapid loss of heat, and the animal dies from cooling. In man it fails at 29° C. in a saturated atmosphere and if he is active and clothed, he suffers from overheating. At 37° and in the absence of clothing, any exertion is practically impossible. In a dry air a man may sit for a time at 100° C. Sutton ('08) states that heat stroke occurs only in a very moist atmosphere (see also Osborne, '10). Aron ('11), working on men and monkeys, found that death from exposure to the tropical sun in the Philippines was not due to any effect of the tropical light (Woodruff, '05; Caskellani and Chalmers, '10), as had commonly been supposed, but to an overheating of the body. This could be prevented by shade or by air currents which increased the evaporation. In conclusion he states: "My experiments demonstrate the enormous physiological and hygienic importance of ample water evaporation in the tropics."

All animals produce some water through the oxidation of the hydrogen in their food. According to Atwater (Hill, '06) man produces about one-third to one-fourth of the amount of water which he gives off through the skin and lungs. Mathews ('13) called attention to this fact in connection with the adaptation of reptiles to desert conditions. Berger ('07) studied the water relations of the meal worm (*Tenebrio molitor*) when kept in dry air and fed on bran which had been dried at 105° C. He considered that the animals were in essentially absolute dryness. Here they lived for weeks but lost weight. He found, however, that the per cent of water in the animals remained practically the same until after death and came to the conclusion that the insect larvae could not use their food to produce water and so the living substance itself was used. No doubt the food taken produced water, but this was not sufficient in quantity. The most important fact brought out was that the per cent of water remained about the same in spite of the extreme dryness and rapid loss of moisture. Pernice and Scagliosi ('95) worked upon fowls which had died of water starvation. They came to the conclusion that the possible water fluctuation of the animal tissues is very small and whenever a cell's water content passes a certain limit, death ensues. Hill ('06) states that with a loss of ten per cent of his weight in water, a man usually dies.

Many animals, such as reptiles, which are dominant in deserts possess thick skins which prevent the loss of water by evaporation. Others, such as reptiles and birds, lose very little water in the form of nitrogenous waste, such waste materials being cast from the body in a nearly dry state. No mechanism to prevent loss of water exists in the common frog; its water demand is supplied through the skin. Durig ('01) found that the common European frog died if the loss of water was rapid when 15 per cent of the frog's weight was withdrawn. If the drying was slow the frogs could lose 30 to 39 per cent of their weight in water without dying. When the weight was reduced to 61 per cent the blood corpuscle count was increased to two and one-half times the normal.

General Summary of Relations to Evaporation and the Reasons for its Determination.—On the basis of the experimental work cited, the reasons for the necessity of determining evaporation in connection with the effects of temperature, moisture, wind movement, and insolation may be summarized as follows:

a. The total effect of air temperature, pressure, relative humidity, and average wind velocity upon a free water surface is expressed by the amount of water evaporated (Hann, p. 72).

b. The same factors have been shown to determine the amount of evaporation from the bodies of organisms (Reinhard '69).

c. Metabolism results in heat and the temperature of the bodies of animals, both warm and cold blooded, is nearly always higher than the surrounding medium, at least during activity (Schaeffer, Vol. I, p. 785). The surrounding conditions may be stated as usually acting on metabolism, etc., as follows: (a) A moist cold atmosphere (very low evaporation) causes body temperature to fall more rapidly than a dry cold one at the same temperature because of the more rapid conduction of heat. Such a fall in temperature *decreases* metabolism of *cold blooded* animals and *increases metabolism* of warm blooded animals within their capacity for heat regulation. In a dry cold atmosphere the heat loss is less pronounced because of the less rapid conduction of heat. (b) In a dry warm atmosphere (high evaporation) rapid evaporation keeps down the peripheral temperature, and prevents death from overheating and destructive metabolism in cold blooded animals, and makes possible body temperature regulation and thus prevents heat stroke and death in warm blooded animals. In a moist warm atmosphere, death and heat stroke occur because of lack of evaporation and lack of peripheral cooling in the case of warm blooded animals, even when the surrounding temperature is at or below the normal body temperature. (c) Wind movement (which increases evaporation) increases radiation of body heat and of heat due to insolation. It increases evaporation and thus further

cools the body, increasing the metabolism of warm blooded animals and decreasing it in cold blooded animals. (d) Decreased pressure increases evaporation and radiation, both of which lower the temperature of animal bodies and influence metabolism, as stated under (c).

d. Conditions which withdraw water from organisms (evaporation as influenced by various factors) influence irritability, activity, and length of life history. Thus Hennings found that low humidity increased insect metabolism and Sanderson found that in dry air the optimum temperature of the growth of insects was lower than in moist air. Thus there are no doubt many exceptions to the usual rules as given under c.

The work summarized above, shows that there is an excellent experimental basis for a statement of the factors controlling the distribution of animals. It is evident that *temperature* data have little significance unless the humidity is known. Neither of these can be interpreted without a knowledge of the pressure, insolation and wind movement. The experimental foundation for the consideration of all these factors in combination, in terms of evaporation, was laid down by Reinhard ('69) and Rubner ('90). The best method of expressing them climatologically was clearly stated by Schierbeck ('95) as the amount of water evaporated. His conclusion is stated as follows: "Bei der Beurtheilung des Einflusses eines Klimas auf die Wärmeregulirung des Organismus und bei der Beurtheilung der austrockenden Wirkung desselben sowohl auf den Organismus als auf leblose Gegenstände ist das Haupt gewicht auf die Geswindigkeit der Verdampfung zu legen." This does not mean that records of the separate factors involved, namely, temperature, pressure, humidity, insolation, wind movement, etc., should not be made, but rather that the best expression of their combined action is the rate of evaporation. The work of Sanderson ('10) shows that moisture is important in insects in connection with temperature. The striking similarity of reaction and survival time to air of similar rates of evaporation on the part of the animals regardless of whether due to *dryness, heat* or *velocity* speaks very strongly for the measure of evaporation in connection with cold blooded animals.

It is a noteworthy fact that the relation of warm blooded animals to climatic factors had been observed (Livingstone, '58) and experimentally studied (Reinhard, '69) (Rubner, '90) before Merriam ('90, '94, '98) published his theory of temperature control. (See also Swain, '05; Craig, '08; Roosevelt, '10; Mathews, '13.) He made a most important contribution in his emphasis of the breeding period. However, Sanderson ('10) has shown that total temperature above an arbitrary minimum is *not* a good index of conditions affecting the growth of insects. There is no good experimental evidence to indi-

cate that such a total temperature is any more significant than total pressure, total sunshine, total wind movement, or (Walker, '03) total humidity. Temperature control has worked in the mapping of distribution just as any theory whatsoever will work for some species, be it concerned with a wandering pole or an Atlantis. The facts and causes of distribution are much more complex than temperature control assumes.

Finally in seeking convenient indices of geographic conditions, we must not overlook the fact that all environmental relations last throughout complete annual cycles and entire life histories. Sometimes conditions during periods when most organisms are inactive are important, for example *winter temperatures* wholly or partially control a large number of plants and animals (Sanderson '08, Shelford '13, p. 177). In all cases indices of the controlling factors are *not* to be found in the total of the selected factor or combination of factors during the entire year or during one particular season, but rather *in the peculiar character of the annual rhythm.*

It should further be noted that meteorological data of any sort, evaporation, insolation, temperature, rainfall, etc., are obtained in a manner which often makes their application to the distribution of most animals impracticable. Such records are taken under conditions of exposure which do not usually represent the animal habitats of the region. Thus in a forested region data should be obtained *in the forest,* in desert regions with full *exposure to the elements.* In the study of both organisms and environment, we have made only a small beginning and the work to date even if fully brought together gives us only a guide to future investigation.

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COASTAL PLAINS AND BLOCK MOUNTAINS IN JAPAN

SUMNER W. CUSHING

CONTENTS

INTRODUCTION.—Opportunity to do the work on which this paper is based was afforded the writer in the spring of 1911, while returning from carrying on geographical research work in India as a Sheldon Fellow of Harvard University. The work was done under the inspirational suggestion of Professor W. M. Davis.

For the geographer, a pleasing approach to Japan is through the far-famed Inland Sea. The route runs from the west gate, on the north side of which stands Shimonoseki—the Gibraltar of that oriental Mediterranean—some 250 miles to Kobe, at the east end of the Inland Sea, where his ocean steamer finds it profitable to make the first stop. Throughout this long stretch, if he is fortunate in weather and if the steamer's schedule covers most of this route in daylight, the geographer will receive a lesson of the highest interest, and at the same time be struck by all those more aesthetic appeals of color, form, and life, for which this picturesque inland sea is noted. Most of the numerous islands encountered are hilly or mountainous and seem to be of volcanic origin. Some are typical of normal drowned shorelines. They are so little forested that even from the passing steamer

it is easy to identify a great variety of land forms in lava and cinders showing many stages of erosion, largely as a result of marine agents. Further, some islands having been slightly elevated exhibit miniature coastal plains about re-entrant margins, while others show the effects of depression in embayed coast lines. From the steamer the varied activities of the farmer-fisher folk can be observed along the terraced slopes, in their unique fishing boats, and even in the villages that crowd the shores in some of the narrows.

At Kobe the western margin of the 20th century Japan is reached. This progressive industrial and commercial region extends to the east along the south coast of Hondo, the principal island, as far as Tokyo, and includes five other leading cities of the Empire, Kyoto, Osaka, Nagoya, Shizuoka, and Yokohama. Location on the south of the island on the route of steamers between the west coast of North America and the east coast of Asia, has meant much in their development. But a larger factor has been the plains between the mountains and the sea which constitute the setting of each. In a country so mountainous that its arable land is less than fifteen per cent. of the total surface, it is to be expected that what limited plains there are will exert dominant influences in the development of centers of population, even when the country approaches the industrial stage of development. This paper treats of these plains, the block mountains that stand in relation of oldlands to them, and their geographical influences.

Outline of Problem.—A glance at the map, Fig. 1, will reveal a series of five bays on the south of the island of Hondo all opening toward the south-southwest, all of nearly the same size, 20 by 40 miles, and of very nearly the same pattern. These are from west to east, the bays of Osaka, Owari, Suruga, Sagami, and Tokyo. Further, it will be observed that each is bordered by a plain that broadens at the bay head on the north and extends into the interior. An exception to this is in relation to Suruga bay where Fujiyama, the great volcano, and Ashitakayama, a composite volcano, have been built up in the area that corresponds to the interior plain in the others. Again, in each region the plains are backed by mountain ranges that extend from north-northeast to south-southwest in sympathy with the longer axes of the bays. Between the consecutive members of the series the region is usually mountainous. Lastly, in almost all of the units there are three centers of population each with distinct activities, one a port, another a manufacturing center, and the third a collective point and trading center for the interior plain: such as Kobe, Osaka, and Kyoto in the Osaka bay district, and Yokohama, Tokyo, and Utsunomiya in the Tokyo bay district.

These strikingly similar conditions and responses hint at similar origins. Studies in the field seem to show, as indicated in Fig. 2b, that

the initial bays resulted from down-faulting of blocks of a peneplained surface, along lines extending north-northeast—south-southwest, and at right angles thereto; that the plains have resulted from two slight general uplifts of the whole region, perhaps of a slanting character, more at the north, little or none at the south, after the basins formed by the depressed blocks had long received the waste from the adjacent

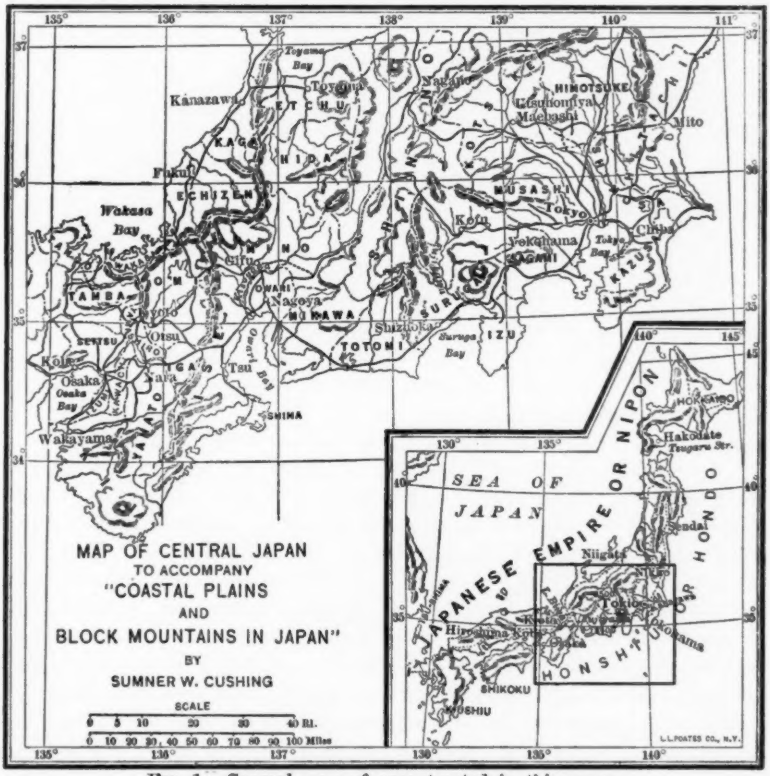

FIG. 1.—General map of area treated in this paper.

mountains. Or, to present the region in the vicinity of the southern shore of Central Japan completely yet concisely, it appears to have been in remote times a region of disordered crystalline structures that was reduced nearly to sea level, and faulted along north-northeast—south-southwest lines and at right angles thereto, into crustal blocks which were in general uplifted and tilted to form block mountains—even now in their youth, but in a few cases depressed to form bays and in one case to form a lake basin. Since then the region has received two slight general uplifts:—the first initiating a coastal plain, at the margins of the bays, that suffered severe marine, as well as

normal erosion—the former aided by a slight depression; the second uplift initiating another coastal plain, which is still young, bordering the former, the mature coastal plain, and articulating with it in the broad valleys.

OSAKA BAY DISTRICT.—Since this district was more extensively investigated by the writer than the others, it is here selected to illustrate the general features shown by all the districts, as well as a few characteristics not seen elsewhere.

PHYSIOGRAPHY—*The Block Mountains.*—The mountains are of complicated structure, from much inclined, little-folded sandstones to distorted metamorphics and huge masses of intrusive igneous rocks. West of Osaka bay the mountains are of granite. On the east they are of loosely consolidated sandstones that strike northeast and dip 50 degrees to the southeast. Farther to the east they are backed by granite mountains to which they stand as foothills. Most of them are grouped in ranges that run rudely parallel from north-northeast to south-southwest, as shown in Fig. 2. A few others extend roughly at right angles to these. Each range is characterized by a gentle slope in one direction and a steep slope in the opposite, by a fairly even crest line (if the volcanoes that some support are ignored), and in many cases, by the striking alignment of the triangular facets at the spur ends of the steep slope, in a manner shown in Fig. 3. These features seem to indicate that the mountains are carved blocks, and that they are in the early stages of post-faulting dissection. This theory as to the origin is further supported by evidence that faulting has been continued into comparatively recent times, as is indicated in the updragged attitude of the strata of some of the mature coastal plains and fans at their inner margin close to the base of the mountain face (found especially in the Owari bay district), as if a recent movement along the fault plane had carried the slightly inclined layers into a nearly perpendicular position. The close association of numerous earthquakes with these mountain bases is in sympathy with this theory. Official investigations seem to indicate that of late years at least, the east portion of southern Hondo—the general area under consideration—has been more subject to earthquakes than any other part of the Empire. In Tokyo the average yearly number of shocks, exclusive of minor vibrations, is nearly a hundred. European residents at Kobe, a city near the mountain base on the west side of Osaka Bay, find it necessary to return home every few years to recuperate, so affected are their nervous systems by the numerous earthquakes and tremors. Fig. 2 shows that according to the theory, Osaka lies over a fault plane. On October 28, 1891, it was the center of a great earthquake that destroyed nearly 10,000 lives. This was the greatest of many recent shocks.

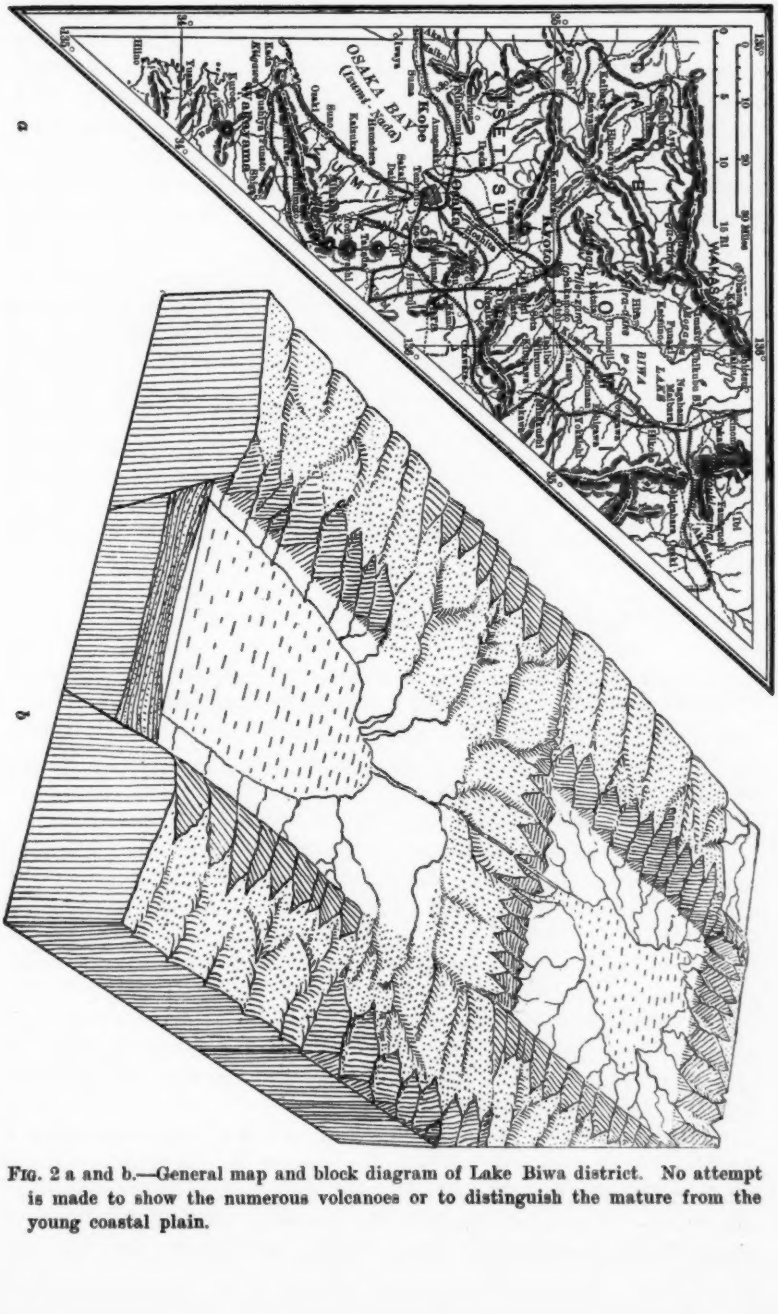

Fig. 2 a and b.—General map and block diagram of Lake Biwa district. No attempt is made to show the numerous volcanoes or to distinguish the mature from the young coastal plain.

The steep slopes of the block mountains face in various directions according to the manner in which the blocks were tilted as they were uplifted. Adjacent blocks sometimes show the steep slopes facing in opposite directions, as is illustrated in Fig. 2b, west and northwest of Osaka bay. Under such a condition the range lacks continuity. From the base of the steep slopes the block edges present truly mountainous aspects because of the rapid ascent and the ruggedness into which the numerous swift-flowing streams have carved the most exposed

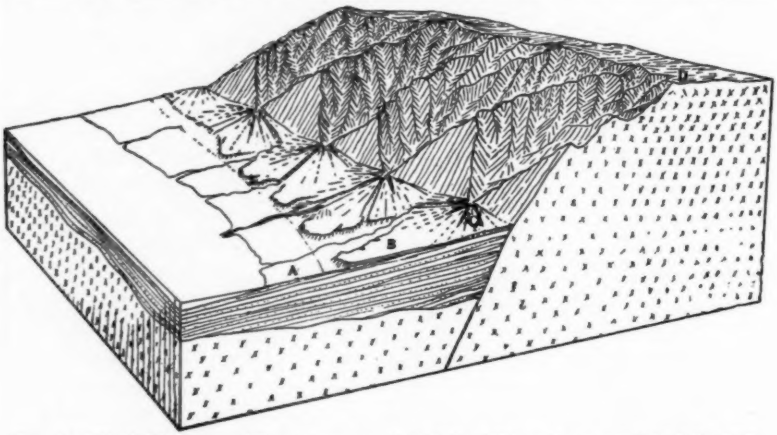

FIG. 3.—Block diagram of the young coastal plain (A), mature coastal plain (B), dissected fans (C), and fault block mountains (D), northeast of Kobe in the Osaka Bay district.

edges, as in Pl. VIIb. From the base of the gentle slope the blocks show no parts rising conspicuously into peaks, as shown in Fig. 6, except those made by volcanic cones.

The evenness of the land in the interstream spaces on the gentle slope shows that the region had been carried well along toward old age before it was faulted and brought into its present elevated and tilted attitude. The mountain growth must have been vigorous since there are few, if any, antecedent streams. The drainage is of the simple consequent type.

The oldlands of districts other than Osaka bay and the west side of Owari bay were only superficially examined, so their classification as block mountains, although supported by evidence that was gathered, is made tentatively.

The Plains.—The plains of this section are of two types: one a combination of a mature and a young coastal plain extending around the bay, that is typical of all the south bays as has been pointed out above; the other, a lake plain at the northeast about Lake Biwa, as shown in the map and the block diagram of Fig. 2. The bay and

the lake occupy basins having such relations to each other and to the block mountains as to suggest that their existence is due to the depression of crustal blocks; the depression of one block developing an arm of the sea because of its relation to the former sea margin, the other making an inland basin holding a lake.

The Coastal Plains.—These plains average only two and a half miles in width, as in Pl. IIa, on the northwestern side of Osaka bay. The young coastal plain takes up about half of this width, as shown in Fig. 3. It is made up of well stratified fine gravels and coarse sands, and has on its outer margin a number of small deltas of finer material. Back of it at the northwest is the mature coastal plain. It is in the form of a series of terrace-like spurs, isolated from one another by extended consequent valleys, and having their upland surfaces at the same general level. The seaward margins of the spurs are elevated sea cliffs, and the lateral margins, valley slopes to the extended consequent rivers, as shown in Pl. Va. Upon the northwest parts of the mature coastal plain are large fans that have been built up by the short swift rivers emerging from the young valleys of the steep slope of the block mountains which constitute the oldland of the plains, as in Pl. VIa. The fans are nearly as conspicuous in size as the spurs of the mature coastal plain, as sketched in Fig. 3. They are now in an advanced stage of dissection. It seems probable that the uplift which initiated the young coastal plain gave the rivers the incentive to bring about this dissection.

The plains gradually widen from southwest to northeast, as shown in Figs. 2 and 3. One cause of this is that the larger rivers emptied more sediment into the head of the bay than along the flanks and so built a very gently sloping bay floor previous to elevation. Again, the northeastern plains being more protected from sea attack, the rivers have added deltas to their margins, whereas in the southwest, beyond the area diagrammed, marine erosion has been so vigorous as to cut away the plains quite to the base of the mountains. Nearer Kobe the mature coastal plain shows by its narrowness and elevated sea cliffs that it suffered almost complete annihilation previous to the last uplift, as indicated in the distant part of Fig. 3.

Just before the rivers cross the line separating the mountains from the plains their courses in many cases are interrupted by falls, as is shown in Fig. 4 and Pl. X. These seem to owe their existence to the recent uplift. Other falls, seemingly those associated with the uplift that brought into being the now mature plain, exist a little higher up in the courses. Thus back of Kobe there is the Men-daki, or "Female Fall," 43 feet high, and a little higher up the On-daki, or "Male Fall," 82 feet high. In the higher courses of the rivers are falls which generally characterize young rivers that flow over vary-

ing structures. The youthfulness of the valleys suggests recent re-entrenchment due to uplift.

On the southeastern side of Osaka bay the plains are wider and more varied in their relations. In the central part, for instance, the mature coastal plain reaches quite to the sea and terminates in a sea cliff that is being rapidly eroded, as is evident in Pl. IVa. This forces the railroad to trench or tunnel through the interfluves of the mature

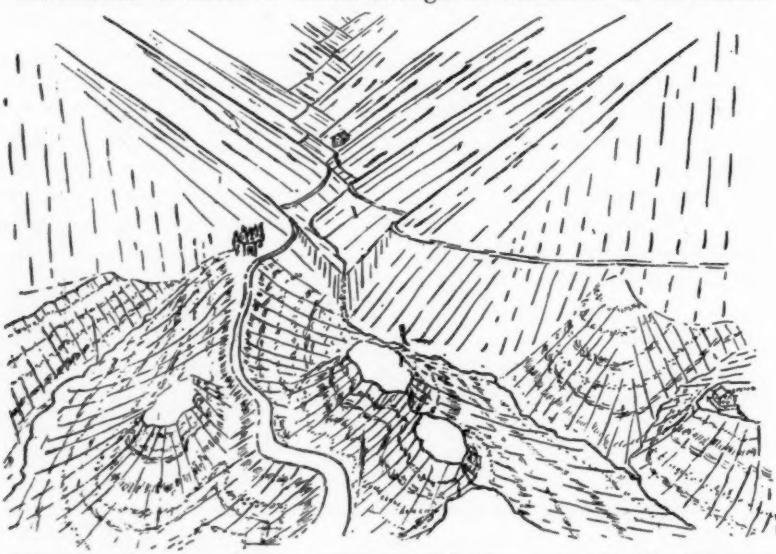

FIG. 4.—At the apex of a much dissected fan looking up an extended consequent valley to the interlocking spurs of the oldland valley, showing a Shinto shrine at the fall line.

coastal plain, while roads along the coast have to climb over them. The sea cliffs permit porcelain manufacturers easily to appropriate the clay from the strata of the mature coastal plain, and carry it away by water, as shown in Pl. IVa.

Another variation is found in the northeast part of this side of the bay where the coastal plains have for the oldland a gently inclined back of a tilted block, as shown in general in Fig. 2b, and in detail in Fig. 6 and Pl. IVb. Here the contrast between the plains and oldland is not so striking in topography, but close examination reveals strong differences in structure, minuteness of dissection, and soil, resulting in very unlike vegetation responses.

Still another variation found on this side of the bay is a general absence of fans at the inner margin. Typical conditions are shown in Fig. 5 and Pl. IIIa. Normal flood plains are found at the lowest level, bordered by valley slopes that lead to the young coastal plain surface

which here reaches quite to the oldland mountain base. The young coastal plain is in turn bordered by longer slopes that lead to the mature coastal plain surface. Lack of fans seems to be the result of weaker oldland structures, as if the rivers were able to keep their valleys graded between the oldland and the plains as the mountain block rose.

Lake Biwa Plain.—The Japanese have great confidence in the legend that Lake Biwa was formed in the year 286 B. C., as the result of a

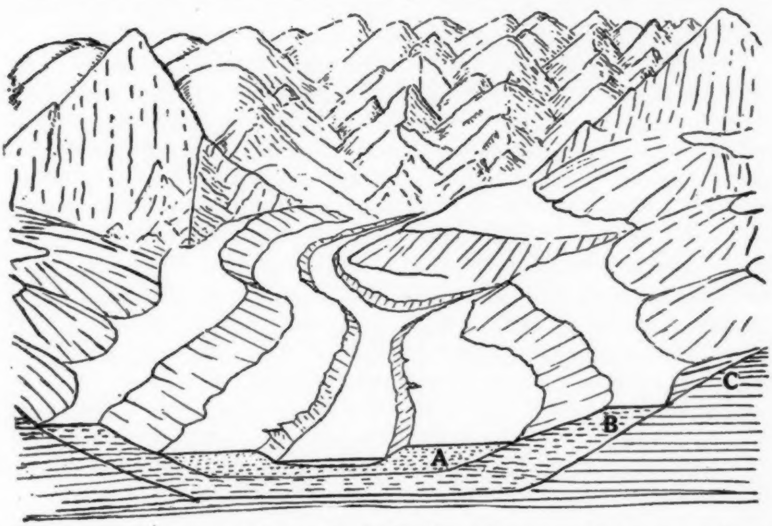

FIG. 5.—In the southeast part of the Osaka bay section, near the inner margin of the coastal plains, looking toward the oldland along the valley of an extended consequent river. A, Present floor plain; B, Young coastal plain; C, Mature coastal plain.

great earthquake. This is not inconsistent with the theory here advanced to account for the basin of the lake. It can be readily seen that if the basin, formed by the depression of a crustal block, had been drained by the cutting down of the outlet and raising its floor by deposition of sediment, the drainage could have been again blocked and the lake reformed by a slight upward movement of the south crustal block, or by farther depression of the basin block, either of which would have been accompanied by an earthquake. However, the legend is not taken as the best support to the theory. That is found principally in the characteristics of the mountain ranges surrounding the basin, which are like those that have been already pointed out in relation to Osaka bay at the south, and which are shown diagrammatically in Fig. 2. If the lake basin be due to the depression of a crustal block, it is probable that the surface of the block dips

toward the west, since on that side the lake reaches nearly to the mountain base at several places, whereas on the east a wide plain intervenes between the lake and the mountains, suggesting shallower waters that allowed the filling of the basin to lake level to proceed more rapidly. From the center of the lake it is observed how completely the basin is surrounded with mountains and how even is the sky line, except where volcanic cones raise their isolated symmetrical summits to greater heights. The even sky line can well be explained on the basis that the blocks which were elevated to form the enclosing mountains, were in prefaulting times reduced to a peneplain.

The plain itself is made up of laterally coalescing fans at the base of the mountain margin and is a typical lacustrine coastal plain around the lake. The surface is interrupted here and there by hills of various origin. Those about the margin seem to be dissected splinters of the upthrown blocks or of later volcanic origin, while nearer the lake there are some that seem to be tops of monadnocks of the depressed peneplained block or small volcanic cones. Some of the hills form islands in the lake.

LIFE RESPONSES—*Shallow Bay Bordering a Young Coastal Plain.*—There are no natural harbors for large vessels in the bays on the south of Hondo because of the gently sloping bay floor associated with the young coastal plain. Small sailing boats find harbor space back of spits made by currents in front of river mouths, as is shown in Pl XIa. Large steamers anchor offshore and communicate with the land for freight and passengers by means of lighters. The site of Kobe was selected in 1868 by foreigners because of a cape just southwest, Wada-no-Misaki, an elevated sand spit, developed before elevation by a strong southwest current working upon offshore sands. This furnishes some protection for steamers riding at anchor. In 1907 there was started a ten years' campaign of dredging and wharfing Kobe's water front in order to overcome the handicap of a gently sloping bay floor and to let the largest vessels receive and deliver goods and passengers with convenience. It is interesting to note that Yokohama, the other port that shares first rank in the empire for value of imports and exports almost equally with Kobe, has exactly the same physiographic setting and has solved its difficulties in somewhat the same way that Kobe is now attempting.

It would seem reasonable to expect that the two leading ports of Japan would be on two of the scores of excellent natural harbors of the Empire, but instead Kobe and Yokohama have grown in spite of their location on bays too large to be considered safe harbors, and too shallow about the margins to facilitate communication with the shore. The extensive plains in the immediate back country of each seem to have forced their rapid growth, while remote deep bays, poten-

tially fine harbors for commerce, but without contributing back-land plains, serve to shelter only fishing craft, junks, or a few coastwise steamers.

The gently sloping bay floor bordering the young coastal plain is taken advantage of by the Japanese in fishing. They drop a net into the bay a short distance from shore. Floaters hold one edge at the surface of the water and the width is great enough to allow the other edge to reach quite to the bottom. The rope-ends of the net are taken ashore and as it is pulled in it makes an effective trap for the fish that frequent the shallow waters. It is obvious how futile this method would be along a deep, rock-bound, ledge-strewn, coast.

Near the head of the bay where the margin of the sea floor slopes very gently, the coast dwellers make the sea contribute a share to their supply of vegetable foods. Rows of tree limbs set out in the shallow water serve as inviting areas of attachment for seaweeds. Only the esculent varieties are allowed to grow—those little deserving the title "weeds." They are regularly gathered by hand at low tide.

Young Coastal Plain — ***High Density of Population and Vegetation.***— It is difficult for a dweller in a new country like the United States to understand what it means thoroughly to utilize the land surface. A visit to the young coastal plains of the various districts offers a striking object lesson in land economy. The Tokyo plain supports about six million people (calculated from the census of 1908) although a rough estimate from the map shows that it contains only 2,500 square miles, which means that the density of population is here 2,400 per square mile. The Owari plain has about a million and a half people in its estimated area of 672 square miles, giving a population density of 2,232. The Osaka plain supports two and a half million people within 400 square miles, which shows that on the average there are 6,250 occupants to every square mile. Belgium, the most densely populated country in the world, with its average number of 652 (1910) per square mile, seems meagerly inhabited when compared with these crowded plains. Most of the people are massed in cities even though they are largely engaged in agriculture; for instance, the three main cities of the plain, Kobe, Osaka, and Kyoto, contain over two million people. Osaka alone has nearly a million and a quarter within her less than nine square miles, giving about 142,000 souls per square mile (Census of 1908). It has been recently pointed out that "the city of greatest density of population appears to be Paris, with 88,000 people to the square mile." [1] How little right Paris has to this distinction is brought out by these statistics of Osaka. Even Manhattan Borough, New York City, has only 106,000 (1910) people to the

[1] The Anthropography of Some Great Cities, Prof. Mark Jefferson, Bulletin of the American Geographical Society, p. 540, September, 1909.

square mile. The great volumetric density of population in Osaka is appreciated even more strikingly when it is remembered that houses in Japan are rarely over two stories in height, and usually one, because of less liability to destruction from earthquakes and danger to life during fires. It can be readily appreciated that every room in every house is used to the fullest extent, that sidewalks are almost unknown, that streets are narrow indeed, and open spaces rare, as is shown in Pls. VIIIb and XIIb.

Outside of the cities, the surface of the young coastal plain is densely covered with profitable vegetation, as illustrated in Pls. IIa and b. Here the phrase "intensive cultivation" has an added significance. Not only are the natural fertility of the soil of the plain, and the water that falls on the plain, fully utilized, but the adjoining less productive regions are drawn upon for contributions to increase the vegetable growth there. The slopes of the dissected oldland yield leaves and twigs from shrubs or trees to be made into fertilizers for the plain. The sea supplies freely of its fish and weeds for the same purpose, and the urban areas contribute cooking waste, fuel waste, and human waste. The rain that falls upon the oldland is carefully conserved to augment the productivity of the plain through irrigation. Rice seems to be best adapted to respond to this concentration of incentives to growth; hence the young coastal plain is an almost continuous checker board of rice paddies when the season permits its growth. At other times cold weather crops such as wheat, barley and peanuts are utilizing the land.

Transportation.—The ease of transportation in any direction over the young coastal plain is an element quite equal in importance to its high adaptability as an agricultural area. The two together explain the rapid progress in the development of industrial centers and commercial ports. Because of the ease of transportation over the plain the movement of goods and people is greatly stimulated so that it is used much for such a purpose, not only among points on the plain itself, but between the oldland and the sea.

Railroads have been extended more over these plains than over any other equal area in the Empire. Fig 1 shows the contrast between intra- and inter-plain routes. Electric lines are confined even more exclusively to the plains, while roads here form a complete network in contrast to the meager number in the mountainous oldland where they are confined to the larger valleys.

Vehicles drawn by men are the most common on the roads of the plain, as shown in Pl. IXb. This is most economical, not only because of the cheapness of labor but because of the ease with which large loads are wheeled over level surfaces. A man would be required to drive a horse or a bull, so it is wise economy to let the man supply

the necessary muscle while he gives intelligent direction. This is true for both freight and passengers. The usual vehicle is narrow, of less than four feet gauge, to fit the narrow roads, as shown in Pl. VIb, and two wheeled, the more easily to make the right angle turns at the corners of the rice fields. It is no wonder that the modern jinrikisha has flourished on these plains since its invention by an American missionary as a means of carrying those who can afford it, since it so nicely fits the environment.

Nearly all of the rivers crossing the young coastal plain occupy channels within confining banks that have been maintained by the people, the better to utilize the waters for irrigation and to prevent floods in rainy seasons, as illustrated in Pl. IIb. The larger ones, moreover, under this condition of control, better serve the needs of water transportation. On the broader part of the plain bordering the bay head, these river canals connect with an extended system of canals whose construction has been greatly facilitated by the low, level land consisting of unconsolidated materials. Osaka is so thoroughly intersected with canals crossed by numerous bridges that it reminds many travelers of Holland's cities. One of these canals is illustrated in Pl. XIb.

Some of the shorter streams flowing across the narrower young coastal plains have aggraded constantly since the confining banks were first constructed, making it necessary to build them higher and higher, until now the bed of the rivers is well above the level of the plain, as shown in Fig. 3 and Pl. IIb. Thus as the railway line approaches Kobe from Osaka, one has the incongruous experience of passing through three tunnels on the young coastal plain, where three rivers have so aggraded their courses that it was found easier to build the railway under the rivers than over them.

Influences of Mature Coastal Plain—Cultivation.—This plain suffers in consequence of two heavy disadvantages that are not found in the young coastal plain. One is that it is now so elevated that practically no water from the larger extended consequent streams can be used for purposes of irrigation; the other that, with mature dissection, level surfaces suitable for rice fields that require almost constant flooding during the growing season, do not exist in mature, as in the young coastal plain, except in isolated portions of the upland surface. The latter disadvantage has been overcome by carefully terracing the slopes. Where they are steep, the terrace field is small and the terrace slope long, as is shown in Pl. XIIa. No matter how much human labor is necessary to build paddy fields, the Japanese are under stern obligation to do so, wherever water can be had for irrigation, because of the paucity of level land, and on account of the great amount of food required by a population of such high density.

It rarely happens that water is obtainable for any extent of the upland surface of the mature coastal plain. Dry crops such as wheat and upland rice, and trees are therefore raised here, as in Pls. VIb and VIIIa. Wherever a consequent or insequent stream is available, there a reservoir is constructed and the slope below terraced for rice, as shown in Pl. IIIa. Between the watered portions of the slopes are often delightful tea plantations, orange groves, or mulberry orchards. Some of the fields are located far from the homes of the owners. To obviate the necessity of carrying implements to and from work many have ingeniously dug caves where thick clay layers of the mature coastal plain are exposed in cliffs, to serve as tool houses, as in Pls. VIb and VIIa.

A Japanese merchant of the Owari bay district, whom the writer visited, has an estate in a narrow consequent valley of the mature coastal plain that well shows nice adaptation of land forms to occupation. His village is called Moroyama, "moro" meaning room, and "yama," hill. The site is indeed "a room made by hills." On a narrow strip of the young coastal plain that articulates with the mature coastal plain, he has rice fields, upon which are grown in the colder season, wheat, barley, and beans. On the lower slopes of the mature coastal plain is a mulberry orchard, on the higher slopes a tea plantation, and on a patch of upland surface of the plain, a grove of trees for supplying fuel. At the lowest level, in easy communication with good roads leading to the railroad, he has a saké factory in which he manufactures the rice into the national strong drink, a soy factory where he converts the wheat, barley, and beans into delicious sauce, a building where he breeds silk worms, another in which girls reel the silk, and still another where the tea leaves are fired. Above, on the flank of the mature coastal plain where the view over his estate is pleasing, he has established a little garden aglow with gay flowers where the employees gather twice a day for lunch and tea.

Temple Sites.—The mature coastal plain has one conspicuous advantage over its related seaward neighbor, in that it offers excellent vantage ground for extensive views. Some parts of the upland margin of the mature coastal plain are in the attitude of promontories to the young coastal plain, as shown in Fig. 6. They give charming views across the garden-like young coastal plain to the distant bay, as in Pl. IIb. In almost all cases, they seem to be reserved as sites for temples and shrines, and for tea houses, as is illustrated in Pl. XIIb. The Japanese have, as is evident in their art, a keen appreciation for beauty in landscapes. Much of their religion is nature-worship. They have gods and goddesses of ocean, mountains, rivers, trees and the like. It is therefore to be expected that they should have selected these highly aesthetic promontories as altars for paying devotion to their nature gods. They have enhanced the beauty of the surround-

ings of these chosen spots by preserving venerable pines and graceful bamboos, and by planting cherry trees, azaleas, oleanders, and other flowering shrubs. Here the dwellers on the lower plain come in family groups, on inviting days, make their simple prayers to the gods, and sit around on nearby tea platforms, which are so placed as to command vistas that delight the eye. Their holy day is indeed their holiday.

Transportation.—The roads on the mature coastal plain are rarely straight or level, as is suggested in Pl. XIIa, in contrast to those on the young coastal plain where they are always so, as in Pls. IIa and IVb. As a result horses rather than men are here used more with wheeled vehicles, since so much propelling power is needed. Men and women,

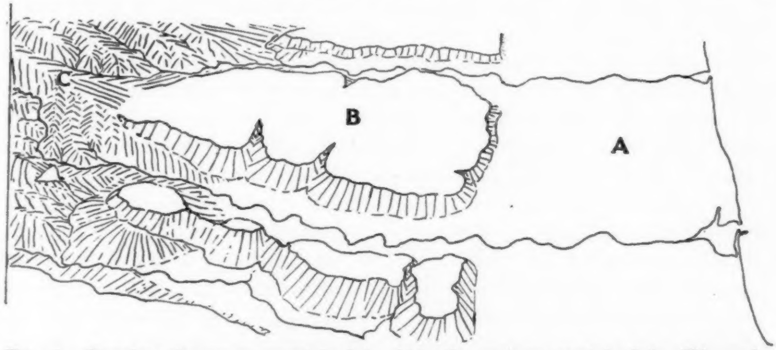

Fig. 6.—Showing the young coastal plain (A), the mature coastal plain (B), and the gently sloping back of a tilted block of the oldland (C), such as is found in the northeastern part of the Osaka bay district.

however, transport many goods by supporting the load on the head, while bulls are used as pack animals. When the jinrikisha is used here, it requires two or three runners. Native travel is almost entirely on foot.

Dissected Fans.—On their outer margin, the fans provoke nearly the same responses as the mature coastal plain because the dissection is about the same. Near the apex, however, erosion has so thoroughly and deeply carved the fans, as is shown in Pl. VIa, in consequence of the greater height, that even the Japanese do not find it profitable to clear the land of its native growth, for other uses, except here and there where some city dweller occupies a remnant of the initial surface of the fan with his summer cottage, as sketched inconspicuously at the right in Fig. 4.

An interesting minor response to environment is found near the apex of many of the fans. At such places the streams usually have falls as is pointed out above, and since waterfalls are considered beautiful and enjoyed by the Japanese, shrines are often located near them.

Fig. 4 shows a typical instance. On several occasions the writer found a rock from the oldland representing the god at these shrines, as if to give travelers from the plains opportunity to put themselves formally under the protection of the new rock god before entering his domain, or if going in the other direction, to give thanks for that protection, while pausing at the fall line.

Lake Biwa Plain.—The young Lake Biwa plain is quite as fertile as the young coastal plain, but it is handicapped as to easy communication with the outside world, being separated from coast centers of population by a mountain barrier. Lake Biwa is over 300 feet above sea level. Therefore, the stream that drains the lake into Osaka bay, the Yodogawa, is interrupted by numerous falls which prohibit its use for navigation. The Japanese have removed the transportation handicap in a way that promises well for the future development of the country. They have dug a new outlet for the lake across a narrow portion of the plain at the south, and then carried it through the mountains in three tunnels of 350 feet, one-half mile, and one and three-fifths miles respectively. This is rudely suggested in Fig. 2b. The difficulty of a fall at the south is overcome by means of an incline, one-third of a mile in length, along which canal boats for passengers and freight are carried in wheeled cradles by means of a cable and an electric motor at the foot of the incline. This is run by a part of the lake water piped to it down the incline, after which this same water supplies a navigable canal that leads to a canalized tributary of the Yodogawa. The other part of the lake water is led to above Kyoto where it furnishes power for mills and factories, and is then used for irrigation. Thus cheap but slow transportation connection for the Biwa plain is made with Osaka bay and much other good is done for industries and agriculture at the same time.

Block Mountains Oldland.—This is the region of meager and scattered population, where man is limited in his activities to forestry, grazing, quarrying, extensive farming, or intensive cultivation on a few small terraced fields with high retaining walls. Here is the main source of the wood that is used for fuel and building by the dense population of the plains. Stone was rarely used in construction previous to the opening of Japan to the outside world, but under European influences, in cities especially, stone is rapidly taking its part in building stairways, breakwaters, piers, paving streets, facing canals, and even in the construction of buildings. The nearness of granite mountains to the cities in the Osaka bay district has done much to foster the quarrying industry. Most of the products of the oldland that find a market on the plains are transported thence on the heads of men and women. Human labor alone is used in tilling the terrace fields, the horse being dispensed with, the hoe displacing the plow.

Potentially these mountains are the power producers for the indus-

tries of the plains because of the youth of the streams that flow in them, and more specifically because of the falls at their steep bases, as is shown in Pl. X. A number of them determine the position of some of the 383 hydro-electric power plants of the country which develop over two million horse power (1912), but many powerful waterfalls of the old land still remain to be harnessed.

In these oldland mountains, as in nearly all mountain districts, the people, because of their isolation, are backward as compared with those of the plains. This is especially true in Japan, for it was the dweller on the plains who heard the knock of western civilization half a century ago, and answered it with cordial hospitality, while the mountaineer as yet scarcely realizes that the Empire has a door.

General Survey of Remaining Areas.—The remainder of this paper will be occupied with brief descriptions of the more striking features of the eastward extension of the plains and mountains, and their associates, as interpreted in a cursory survey. Place names used are to be found in Fig. 1. They are given with the hope that some of the readers may have opportunity to visit this attractive country and will have the inclination to extend the study here briefly presented.

On the west of the Owari bay district the railway runs along the young coastal plain tangent to the forward spurs of the mature coastal plain, sometimes turning westward into a broad valley floored by the young coastal plain to take in some village or to find a better place for crossing the wide, shallow rivers. Due west of Yokkaichi, a river mouth port of the young coastal plain, one of the spurs of the mature coastal plain attains an altitude of 230 feet. From this point a magnificent view is to be had of the wide young coastal plain, covered with intensively worked plats and dotted with numerous villages, as shown in Pl. IIb.

Toward the head of Owari bay, a Dutch air is given the outer margin of the young coastal plain, at a few places, by dikes that reclaim for farming land, areas that would otherwise be merely salt marshes. Movable dams let the surplus fresh water off at low tide and prevent the ingress of salt water at high tide.

As Okazaki is approached from Nagoya, the surface of the mature coastal plain is so continuous that the railroad rises gradually to it and follows it for long stretches before dipping into shallow valleys of simple consequent rivers.

Between Toyohashi and Hamamatsu is the large " lake " of Totomi. Its floor is an uninitiated portion of the young coastal plain. At its east and west margins the waves are beating at the bases of the slopes of the mature plain. Sand spits are building across the entrance of this lagoon by tying up the outlying islands—fragments of the mature coastal plain—making an excellent roadbed for the railroad. The

entrance is now about a third of a mile wide. It is said that previous to the year 1499 the lagoon had been closed from the sea long enough to make it fresh, but in that year, an earthquake destroyed a portion of the natural barrier. Salt pans are now worked at favored places along the shores.

As the railroad approaches Kakegawa after crossing the Tenryugawa, it gives an excellent view of the land forms under consideration. It first shows the young coastal plain, then the much dissected outer part of the mature coastal plain, and then less and less dissected portions toward the inner margin. Many cuts here give fine views of the characteristic structure of the mature plain. Kakegawa is about ten miles from the sea and separated from it by a huge outlier of the oldland about which there is a high terrace of the mature coastal plain.

On the south of the Oigawa the surface of the plains is covered by an immense lava flow that seems to have had its source up the Oigawa valley.

As the Fujikawa is approached from Shizuoka, there is a stretch of coast from which the mighty attack of the Pacific in the more open bay of Suruga has removed all trace of the plains. Not enough is left to permit the railroad to go between the oldland and the sea. It is forced to tunnel in oldland rock. But directly at the northeast the young coastal plain is just wide enough to take the track; beyond, it is wide enough for a row of houses besides; farther, it takes a row of fields as well; and still farther, it is wide enough for good-sized villages and their agricultural associates. Then the typical forms representing the mature coastal plain appear, here 60 feet above the lower plain. A few miles beyond an exceptional feature is shown in a 10-foot sea-cliff at the outer margin of the young coastal plain.

After crossing the Fujikawa, lava flows and cinder accumulations from Fujiyama dominate all other land forms until Kozu on the Sagami bay is reached. Here the mature coastal plain comes within 100 yards of the shore and the young coastal plain is cliffed 30 feet. As the coast gets more and more exposed at the north, this cliff increases in height. The surface of both plains is here disguised by dunes of volcanic ashes, few of which are used for agricultural purposes. Near Ofuna a heavy lava flow appears on the plains.

In Yokohama the native quarters, the business section, and most of the hotels are on the young coastal plain, while the residential section for the Americans, Europeans, and well-to-do Japanese is on the mature coastal plain, "the Bluff" in the vernacular. Residents of the Bluff have been much hindered in the past because of the difficulty in getting water in times of fire and even for ordinary purposes, because the city's reservoir was on a fragment of the initial surface of the mature coastal plain only slightly higher than the Bluff level. Now a new reservoir is being completed several miles to the west of

the city on the higher parts of the mature coastal plain. The city is bounded on the north by one spur of the mature plain; on the south by another; and a third, between them, intrudes itself quite to the center. From the summit of the forward part of the third spur, the Noge-yama, an excellent view is to be had of the whole city, the harbor, and on clear days, of Fujiyama. It is reached by a flight of a hundred stone steps, as shown in Pl. XIIb, and is crowned, as might be expected from earlier observations on such points, by shrines of both Shinto and Buddhist gods, and by tea houses.

From Yokohama to Tokyo both plains widen gradually. The railway runs tangent to the projecting spurs of the mature coastal plain, and has large station villages at the points of tangency, as is often the case elsewhere. Yokohama has taken vast amounts of sand and clay from the higher plain north of the city for building up the low land along the coast, exposing fine cuts showing structure. In Tokyo the young and mature plains determine the topography. Here the mature plain is thoroughly dissected, forming many more or less isolated hills of varying heights, as well as miniature plateaus. Upon these are located parks, palaces, observatories, and schools, as well as many temples. To reach many of them, it is necessary for the traveller to leave his 'rikisha on the young coastal plain and climb a steep slope. He often has the choice of the men's staircase, which is straight and difficult, or the women's staircase, which is circuitous and more comfortable. The average height of the mature coastal plain is about 75 feet, thus conveniently permitting 100 steps to be made in the staircases, which is one of the magical numbers in Japan. The southern half of the city occupies an area that was naturally the northern part of the Tokyo bay or lagoons. It was reclaimed several hundred years ago by the use of earth taken from the fragments of the nearby mature coastal plain.

Conclusion.—The whole region of Central Japan here considered is eloquent to the geographer of the inconstancy of the position of the boundary between the land and the sea, and of the strong and varied influence of land forms upon an insular people who have been compelled to adapt themselves nicely to their environment under the high pressure of a dense population.

The recent rapid growth of the land, physiographically, in this region may be taken as symbolic of the recent rapid growth of the people, historically, in modern culture. The block mountains may be taken to stand for Japan's high and ancient oriental civilization—conservative and exclusive of modern activities—like the mountain people among them; while the coastal plains, recently uplifted, stand exposed to the pulsating, vitalizing influence of the ocean, anxious to be recognized as the best favored of their kind, even as the people who occupy them.

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ECONOMIC ASPECTS OF THE GLACIATION OF WISCONSIN *

R. H. WHITBECK

CONTENTS

INTRODUCTION.—Investigations, more or less thorough, have been carried on for the purpose of determining whether or not the soil of the glacial drift is superior to the soil of the adjacent area beyond the terminal moraine. Most of the published reports of these investigations state that the glacial drift is more productive than the older soil in the same general region. It is quite commonly believed that the mantle of drift spread over the northern United States, excluding parts of New England, has made better soil than would otherwise have characterized this area. There are areas in the upper Mississippi Valley which were not improved for agricultural purposes by the kind

* This paper is the outgrowth of three closely related pieces of work. Some of the preliminary work was presented in a paper at the Pittsburg meeting of the Association of American Geographers, in December, 1910, and was published in The Bulletin of the Geographical Society of Philadelphia, July, 1911, Volume IX, No. 3. A very considerable amount of additional work was done under the writer's direction by Miss Mildred Aldrich and was presented for a graduation thesis in the University of Wisconsin in June, 1912. Further work was done by the writer, and a summary of the results was presented at the Princeton meeting of the Association, January 1, 1914.

of drift deposited upon them. Such, for example, are the sand barrens in northern Wisconsin and Michigan. So commonly is it stated that glacial soils are of superior quality, and so generally is it assumed that the net effects of glaciation have been economically beneficial to man, that few people seem to have taken the opposite view.

Agricultural reports show, however, that one of the very best farming counties in Wisconsin, Lafayette County, is in the driftless area. The notable excellence of some of the farm lands in other parts of the driftless area seemed to cast doubt upon the general thesis that glacial soils are of better quality than the residual soils of those same regions would have been if no glacier had disturbed them. A member of the field staff of the Wisconsin Geological Survey expressed doubt regarding the general superiority of the glacial soils in the State as compared with the non-glacial. It seemed worth while, then, to take up the problem and to apply as many tests, from as many different angles, as possible.

The investigation was not undertaken for the purpose of proving either the affirmative or the negative of the question, but to establish the facts in the case, whatever they might prove to be. No factor which might affect the results has knowingly been omitted. When, for example, areas were to be compared with respect to value of land or crops, an effort was made to select two areas which have an equally favorable location with respect to large cities, for cities invariably increase the value of farm land and farm products in their neighborhood. Furthermore, the comparisons have been made in a variety of ways and with many areas, in the hope that mere accidents or exceptional conditions may be deprived of any material effect upon results. The inquiry was later broadened so as to include other economic aspects of glaciation besides the agricultural, such, for example, as the effect of lakes and water power.

The State of Wisconsin offers an exceptionally favorable area for this comparative study, for reasons which will appear. The northern half of the State is omitted from consideration because (1) it is geologically unlike the southern half, and (2) it is in a wholly different stage of economic development. Only a minor part of northern Wisconsin is agriculturally improved. But the eastern and western portions of the southern half of the State are underlain by the same kinds of rock, have been settled and cultivated the same length of time and so have had equal opportunity to prove their respective agricultural and other possibilities. It is true that three of the counties in the Driftless Area, owing to valuable deposits of lead (also zinc), were well populated earlier than any of the glaciated counties. Otherwise, the settlement of the driftless area and of the glaciated area went on at much the same rate. The driftless region is crossed by the Missis-

sippi River, a fact of consequence during several decades when that river was an important commercial waterway. On the other hand, the glaciated area has Lake Michigan on its eastern border, a fact of large importance in later years.

General Features of the Driftless Area.—This region includes over 9,000 square miles in the southwestern quarter of the State, overlapping very slightly the adjacent parts of Iowa, Minnesota and Illinois. Time after time in the geologic past, great lobes of the glaciers which pushed into the upper Mississippi Valley have advanced upon this region, sometimes entirely encompassing it, yet never covering it. So far as I know, no other spot in the world has had such an experience. Glacial geologists who have worked in the upper Mississippi Valley and especially in Iowa, believe that they have conclusive evidence of several glacial advances and retreats separated by long interglacial epochs. In each of the advances the ice has closed about the driftless area, sometimes on three sides, sometimes on all sides. This fact becomes still more striking when it is known that the driftless area is not an elevated region. On the contrary, much of it is about the lowest part of the State, including portions of the Wisconsin and Mississippi Valleys that slope and broaden toward the south. The halt of the ice-front in practically every instance occurred on lands of small relief; so the glacial advance was not checked by any barriers in the topography of the driftless area itself.

A discussion of the cause of this peculiar phenomenon is not intended here. It will be found in the 6th Annual Report of the United States Geological Survey.[1] Suffice it to say that the cause, whatever it may have been, persisted for a long time, for it was equally effective in every one of the glacial epochs, which together involved a vast period of time. This cause is believed to be connected with two facts; one, that the driftless area lay approximately between the western margin of the Labrador ice sheet, and the eastern margin of the Keewatin sheet; second, the fact that the highland of northern Wisconsin and Michigan diverted the ice of the Labrador sheet to the right along the Lake Superior depression, and to the left through the Lake Michigan and Green Bay depressions, and that the latter was not able to unite with the ice on the west of the driftless area until it had pushed well to the south, leaving an intervening area unglaciated.

The driftless region of Wisconsin is essentially a lowland gently sloping toward the Mississippi and Wisconsin rivers. The geological formations which underlie it are the same as those which underlie the glaciated portion of southern Wisconsin. There is no reason to suppose that the preglacial topography of one part of southern Wis-

[1] By T. C. Chamberlin and R. D. Salisbury, pp. 205-322; Origin of the Driftless Region, p. 315. Washington, D. C., 1886.

consin was greatly different from that of the other, for that topography was based upon the underlying rock formations which are substantially the same in the drift covered area as in the driftless area. This is especially true of a strip eighty miles broad extending across the southern part of the State. Furthermore, a great number of well records collected by Alden and Thwaites shows that the buried preglacial topography has a relief practically equal to that of the present driftless area.

Now, however, there are marked topographic contrasts. In fairness it must be stated that these contrasts are not such as to impress the ordinary traveler. Furthermore, there are just as striking contrasts between different parts of the driftless region as between the driftless and glaciated areas. In fact, there are greater differences between the sandstone region and the limestone region within the drift-

FIG. 1.—Cross section through a portion of the Driftless Area (Richland Co.), showing rough topography.

FIG. 2.—Cross section through a portion of the Drift Covered Area (Columbia Co.) directly west of the region shown in Fig. 1, and on the same scale.

less area, than any differences which have resulted solely from glaciation. Rarely is it possible to note just when you pass the border from drift to driftless country. The state geological survey recognizes drift of several different ages, the older underlying the younger, but protruding here and there. The last—or Wisconsin—drift sheet everywhere terminates in a conspicuous belt of hilly moraines from two to twenty miles broad. But in many cases the earlier drift-sheets have absolutely no terminal moraine; they simply blend into the driftless region imperceptibly, and even a trained observer frequently cannot tell where the older drift sheet ends.[2] Of course, outwash material often extends considerably beyond the line actually reached by the glacier.

Geologically the surface rocks of Wisconsin may be divided into three groups. Most of the northern half of the State is a region of ancient crystalline rocks. The middle portion is a region of rather soft Cambrian sandstones. This is enclosed on three sides, east, south

[2] Chamberlain and Salisbury, Preliminary Paper on the Driftless Area, 6th Annual Report, U. S. G. S., 1886, pp. 210, 211.

and west, by limestones, under which the sandstone lies. The driftless area is practically all in the sandstone and limestone belts. Probably the limestone originally completely covered the sandstone, as it now covers it on the southern, eastern and western portions of the State. The limestone is resistant. The underlying sandstone is weak.

FIG. 3.—Generalized map showing the three main classes of rock in Wisconsin and the boundary of the Driftless Area. From Bull. XXVI, Wisc. Geol. and Nat. Hist. Surv.

When streams have eroded their valleys through the overlying limestone and are working in the softer sandstone below, a characteristic type of topography is produced. The limestone remains as a capping layer on top of the hills. The underlying sandstone weathers back readily on the valley-sides as far as the capping layers of harder limestone permit. This produces a series of branching valleys separated by mesa-like divides. The drainage of this region is mature and developed with remarkable symmetry. The streams branch and the branches subdivide in dendritic pattern (Figs 6, 7). Many of the hill tops are flat, and the valley sides steep; the streams flow in well-graded channels;

there are no lakes and no waterfalls; swamps are absent, except in certain sections near enough to the glacial border to have their streams clogged by outwash or valley trains.

Further south, while the steep-sided valleys with the mesa-like uplands between are not seen, the drainage pattern is, nevertheless, perfectly dendritic, and orderly topography greets you on every hand.

Topographic Features of the Glaciated Area.—Pass now to the area covered by the latest drift. At once a change occurs. The valleys are filled or half filled with mounds and hills. There is no uniformity in the details of the landscape. The symmetrically branching valleys which characterize the driftless area in the limestone region are nowhere in evidence. Streams wind about in confusion. Headwater divides are difficult to locate. There is no system to the stream courses. A branch stream may flow nearly north to join a trunk stream that flows nearly south. Large areas have no drainage, and swamps and lakes are met with on all sides. The one impressive fact is that everything on the surface is disordered and yet to it all there is a rounded and graceful contour.

The work of the glacier in the non-resistant sandstone was a crushing and leveling process. In the resistant limestone, the glacier rounded off the elevations and eroded some valleys a good deal, tending on the whole to a reduction of the relief and an obliteration of most of the steep slopes.

Differences in Drainage Systems.—The most conspicuous of the contrasts between the two portions of the State is the prevalence of lakes and swamps in the glaciated region and the entire absence of lakes and the rarity of swamps in most of the driftless region. (Figs. 4 and 5.)

A map of the drainage system of the Wisconsin River (Fig. 6) brings out some emphatic contrasts. I know of no other case in which a single river system presents four such distinct types of drainage. The river is about 400 miles long. Its headwaters include such a labyrinth of lakes and lakelets (said to be 1400) that many of them cannot be shown on a map of ordinary size. The northern quarter of the course of the Wisconsin is thus an extreme type of glacially obstructed drainage.

The second quarter of its course is through the older drift. Every lake has disappeared. The swamps are drained. The tributaries divide and subdivide and the tree-like pattern is completely developed.

The third quarter is as youthful as the first, but of a wholly different type. Here the river traverses a wide sandy plain of recent origin. Few tributaries have yet developed.

The last quarter is in the driftless part of the limestone area, and the pattern shows how completely the river and its branches have

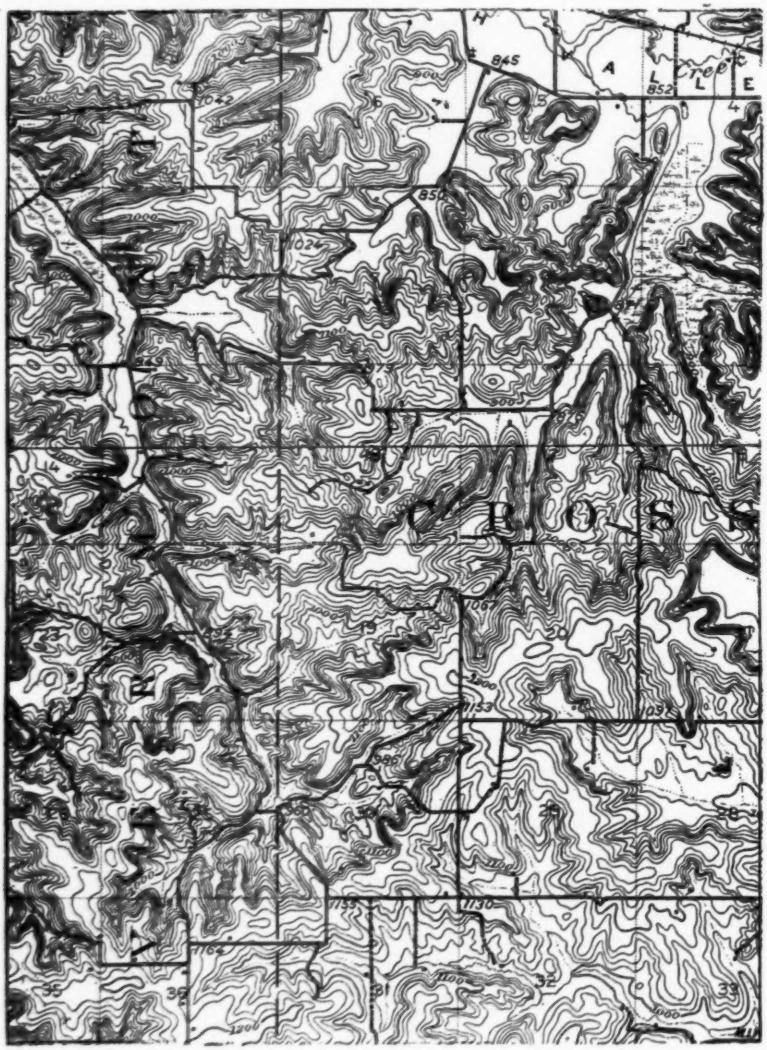


FIG. 4.—Driftless Area, Wisc., immediately west of terminal moraine.

penetrated every square mile and established a perfect system of drainage.

The eastern half of the Rock River basin is in the drift and the western half in the driftless area. The map tells its own story (Fig. 7). The well-nigh perfectly graded courses of the main streams in the driftless area are not favorable to the development of water power.

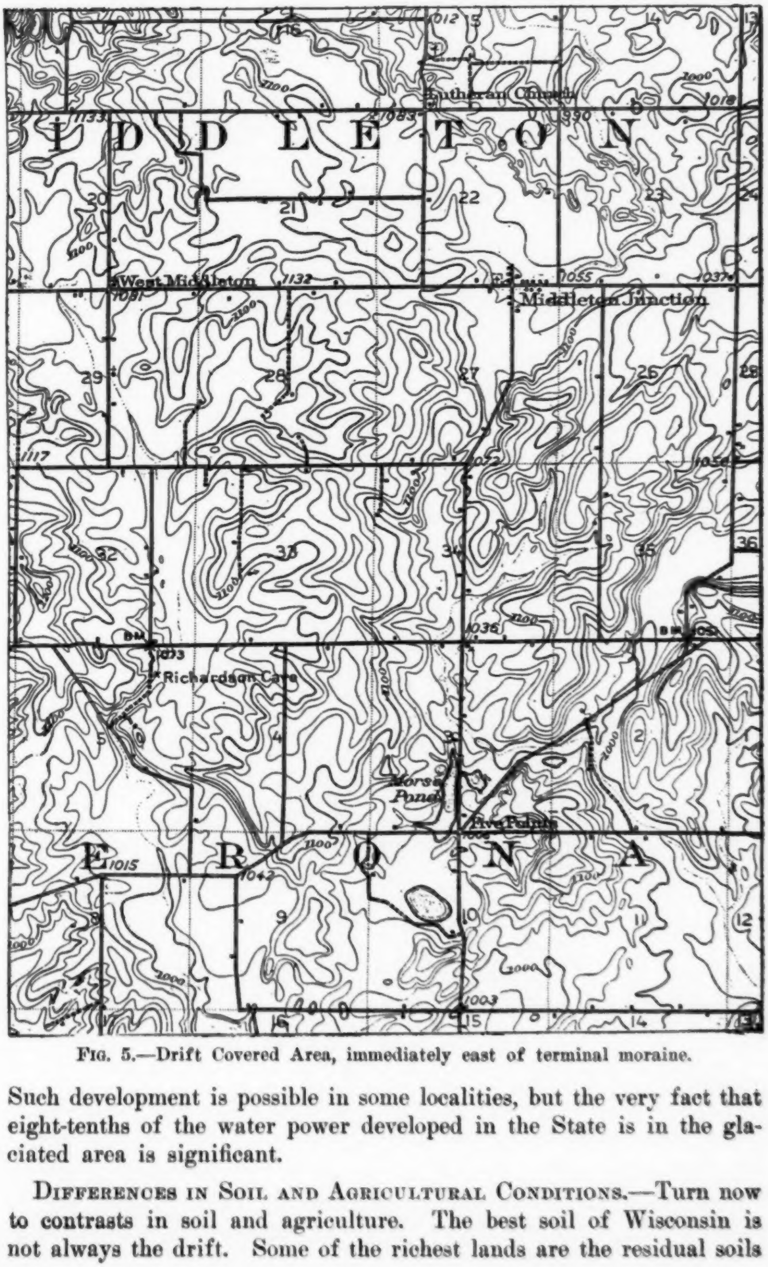


FIG. 5.—Drift Covered Area, immediately east of terminal moraine.

Such development is possible in some localities, but the very fact that eight-tenths of the water power developed in the State is in the glaciated area is significant.

DIFFERENCES IN SOIL AND AGRICULTURAL CONDITIONS.—Turn now to contrasts in soil and agriculture. The best soil of Wisconsin is not always the drift. Some of the richest lands are the residual soils

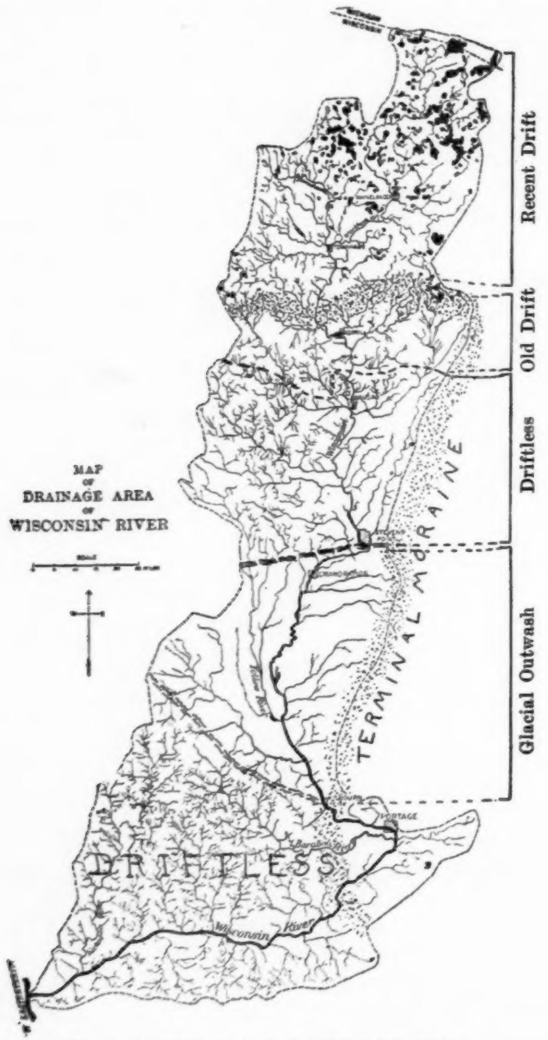


FIG. 6.—Drainage Area of Wisconsin River.
(Modified from cut in Bull. XX, Wisc. Geol. and Nat. Hist. Surv.)

of the limestone area, over parts of which loess has been distributed. The poorest are in the sandstone area. The older drift is often better soil than the adjacent younger drift. The limestone soils, whether residual or transported, are decidedly superior to the sandstone soils.

In discussing the effects of glaciation upon agriculture, it will not be forgotten that the glaciers brought in enormous quantities of bould-

ers, and introduced hundreds of swamps and lakes at the same time that they were performing the beneficial work of mixing and introducing new soil and smoothing the surface of the land.

Proportions of Improved Land in the Driftless and Glaciated Areas.—According to the United States Census of 1910 the fifteen counties which are wholly or largely in the driftless area consisted of 43.5% improved farm land and 56.5% of unimproved land. The 26 counties (in the southern half of the State) which are wholly

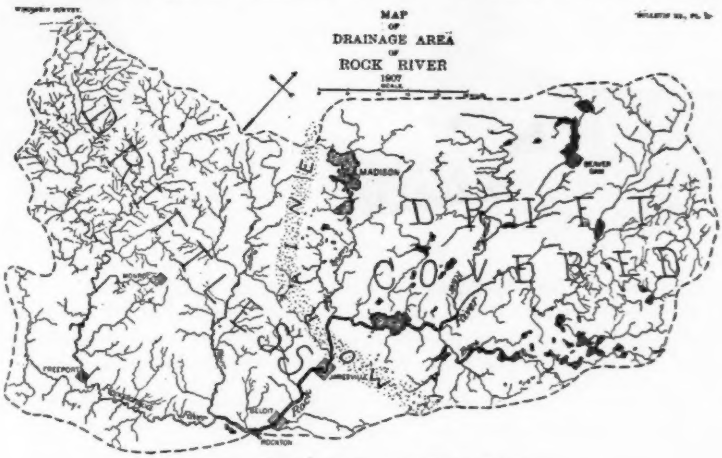


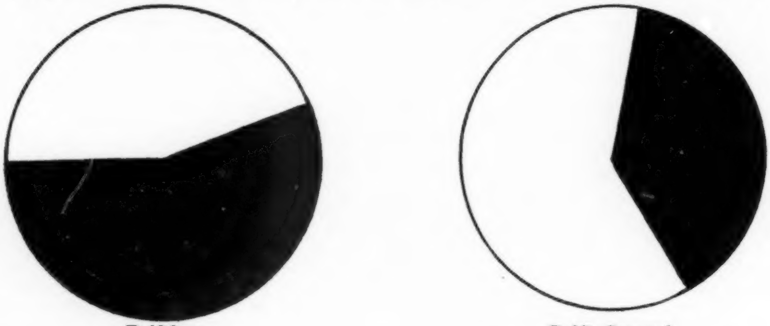
Fig. 7.—Drainage Area of Rock River.

or largely covered with drift, consisted of 61% of improved farm land and 39% of unimproved land, an excess of 17.5% over the driftless area.

The State Census of 1905 shows that in the fifteen driftless counties, the average value of farm lands and farm buildings per county was, in round numbers, $12,000,000, while in the 26 glaciated counties the average value was nearly $18,000,000 per county. On account of the greater number of cities in the glaciated area, and the consequent influence of these in increasing the value of neighboring farm land, the actual bearing of these figures upon the present question is complicated.

For purposes of definite and careful comparison, twelve typical counties were chosen, six in the sandstone belt and six in the limestone. Of all the land in three driftless sandstone counties, 37.2% was improved farm land in 1910, while in three glaciated sandstone counties, 48.2% was improved, an excess of 11% in favor of the glaciated area. In the three glaciated sandstone counties, the value of all crops per square mile was about $400 more (10%), than in the three driftless

sandstone counties. Of all land in three driftless limestone counties, 60.5% was improved in 1910, while in an equal number of glaciated limestone counties the per cent was 70.3, a difference of 10% in favor of the glaciated lands. The difference in productivity is notable, being about $1,400 per square mile—31%—greater on the glaciated limestone soils of these counties than on the driftless soils. In this area



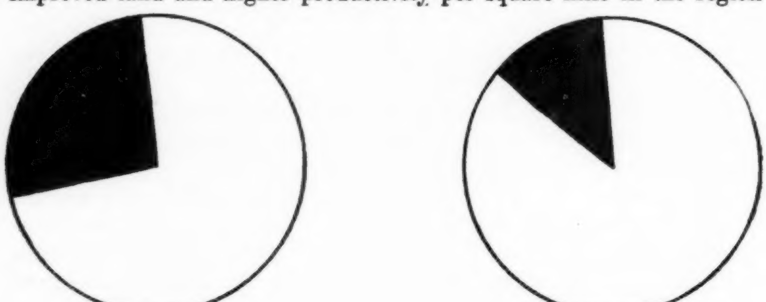
Driftless
White—Improved Land, 43.5%
Black—Unimproved Land, 56.5%

Drift Covered
White—Improved Land, 61%
Black—Unimproved Land, 39%

FIG. 8.—Proportion of unimproved land in 26 counties wholly or largely drift-covered, and in 15 counties wholly or largely driftless.

the limestone lands seem to have benefited more by glaciation than did the sandstone lands.

The question naturally arises, why is there a larger percentage of improved land and higher productivity per square mile in the region



Driftless Area, 26% Drift Covered Area, 12%

FIG. 9.—Proportion of land in woodland and woodland pastures in Driftless Area and in Glaciated Area.

over which the drift is spread? Two explanations are possible: (1) drift soil may be better than residual, or (2) drift topography may be smoother, permitting the cultivation of more of the land. The high prices of farm land and of farm products make it seem altogether likely

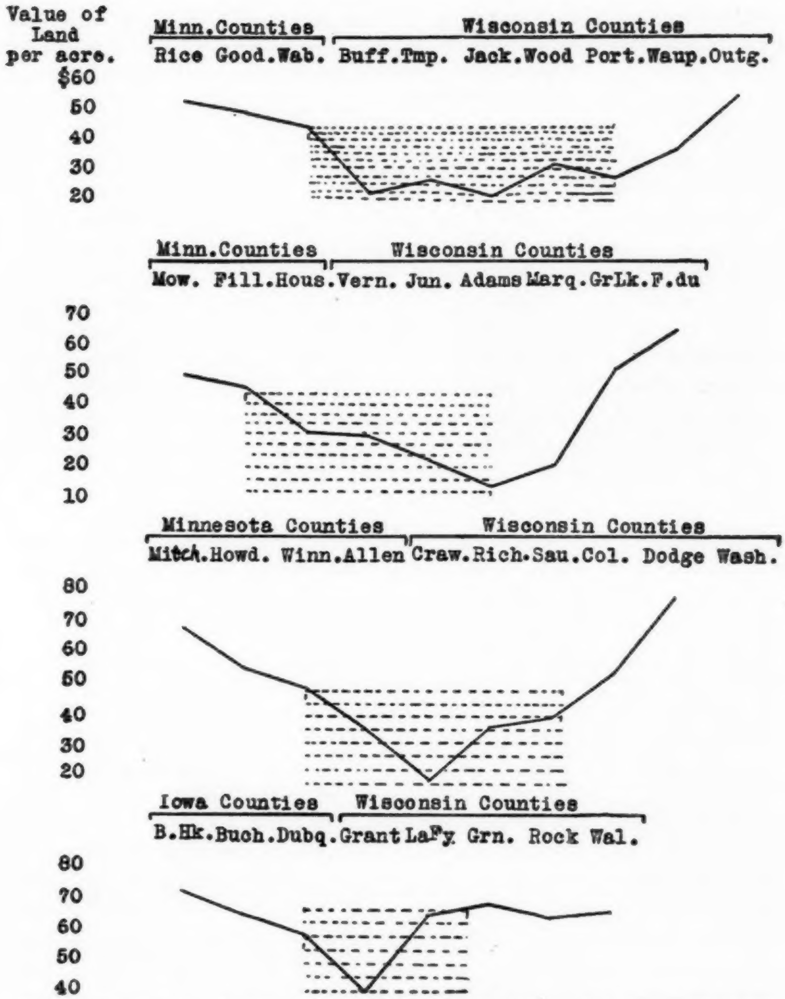


FIG. 10.—Curves showing the average value of farm land and farm buildings per acre in four rows of counties extending from the Glaciated Area on the west across the Driftless Area into the Glaciated Area on the east. Cross lined portions are driftless.

that, in any of the older counties, as much of the farm land will be improved as possible. In southern Wisconsin, about the only land which is left unimproved is swamp land and steep hills. A trip through southern Wisconsin, or an inspection of topographic maps, shows that the swamps are mostly in the drift covered area, but that the topo-

graphy in the driftless area (in the limestone belt) is much rougher. The mantle of drift naturally reduced the relief of the land over which it is spread, and rendered a larger proportion of it fit to cultivate. Computations, based upon U. S. Census figures of 1910, show that while 27% of the driftless area of southern Wisconsin is allowed by its owners to remain in woodland or woodland pasture, only 11% of the drift area is allowed so to remain. Since the woodland and woodland pastures are largely those parts of the farm which are hilly and so are difficult to cultivate or mow, it appears that there is more than twice as much such land in the driftless area of southern Wisconsin as in the glaciated. The driftless area averages over 126,000 acres of woodland per county, while in the drift covered area under consideration, there are only about 50,000 acres of woodland per county. From this it seems that the drift sheet added some 75,000 acres per county to the land that is smooth enough to cultivate or mow. To offset this in part, there are, *on an average,* some 40,000 acres of swamp land per county to be charged against the glacier, leaving a net gain of something like 35,000 acres per county.

Value of Farm Land and Farm Buildings.—The problem was next attacked along the line of the comparative value of farm land including buildings. Four rows of counties, beginning in the glaciated area on the west, crossing the driftless area and ending at Lake Michigan on the east, were selected. Figure 10 shows the counties which are considered. In each county the average value per acre of farm lands, including buildings, was found (U. S. Census of 1910). These values are graphically shown in Fig. 10. It will be noted that the curves all trend downward as they are entering the driftless area from the west, and all except one trend abruptly upward on the east, when they pass out of the driftless area into the drift. Without an exception the counties in which the average value of land is lowest, are in the driftless area. (In fact the average value of the farm lands and buildings in the drift covered counties is about double that in the driftless counties.) The real point here brought out is easily misunderstood. It is entirely possible that there is some land in the driftless area which is equal to the best in the drift, but the *average value per acre of all the land in a given county* is invariably less in the driftless than in the glaciated counties in each row. This may result either from (1) the superiority of the glacial soil or (2) a smoother topography. At this point, no effort is made to determine which is the case. When the figures are placed in columns and the average of each column is found, the results are impressive. [Figures from U. S. Census of 1910.]

Average Value per Acre of All Farm Land in 39 Counties

Drift.	Part Drift.	Driftless.
$45.50	$42.20	$24.40
28.00	32.35	28.20
38.50	46.70	23.10
55.50*	51.00*	32.75
57.75*	62.00*	32.55
52.20*	70.75*	25.70
45.00		17.25
52.00*	$305.00	38.25
22.00	Average, $50.80 per acre.	21.50
51.00*		39.60
67.50*		40.60
65.30*		41.40
57.25*		68.00*
56.60*		
80.00*		$433.30
62.00*		Average of 13 counties,
96.00*		$33.30 per acre.
67.60*		
70.10*		
69.40*		
$1,139.20		

Average of 20 counties, $56.90 per acre.

* Counties with average value of all land above $50.00 an acre.

In the above figures, two Wisconsin counties which contain cities of considerable size, and another county lying near Milwaukee, are omitted from consideration. If these were included, the average value of land in the drift-covered region would be still higher. It will be noted that in fifteen out of the twenty glaciated counties, the average value of all land is above $50.00 an acre, while in only one of the thirteen driftless counties is this true.

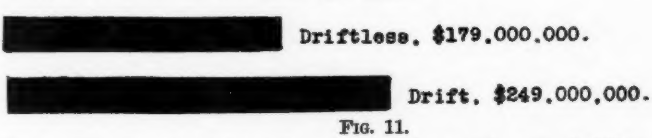


Fig. 11.

No. 1 represents the total value of farm land and farm buildings in fifteen driftless counties in 1910 (U. S. Census).

No. 2 represents the same for fifteen glaciated counties, lying immediately east of the former.

A fact quite unconnected with character of soil accounts for a portion of this difference in the average value of farm land; the Mississippi River flows through the driftless area, and this river and its tributaries have cut the land into a region of steep hills and narrow valleys, a kind of topography unfavorable to agriculture.

In value of farm lands and farm buildings, four *average* counties

in the drift area exceed the four *best* agricultural counties in the driftless area.

Comparative Value of Crops.—The next comparison aimed to discover the relative productivity of glacial and non-glacial soils. Comparisons were first made between the glaciated and driftless parts of the four counties which are crossed by the terminal moraine. Two of these, Portage and Sauk counties, are in the sandstone belt; and two others, Dane and Green, are in the limestone belt. The average value of all crops per square mile was (in 1905) $1,968 and $2,690, for the driftless parts of the sandstone and limestone counties respectively. For the glaciated parts of the same counties it was $2,776 and $3,828 respectively for the sandstone and limestone belts. In each case the value of all crops per square mile of territory is over 40% greater in the glaciated parts of the counties than in the driftless parts of the same counties. (Fig. 12.)

Fig. 12.—Average value of all crops per square mile in the driftless and glaciated halves of four counties crossed by the terminal moraine. Over 40% difference in favor of glaciated lands. Upper two are limestone counties; lower two are sandstone counties.

The next comparison was made by taking two continuous chains of townships, one chain parallel to the terminal moraine and about 6 or 8 miles from it on the driftless side of the moraine, and the other chain on the glaciated side. In the sandstone belt, the average value of the five leading crops per square mile was 11% greater in the glaciated than in the driftless townships, while in the limestone belt it was 36% greater. Comparing all of the driftless townships with all of the glaciated townships, there was an excess of 23% in favor of the drift-covered lands.

Next, twenty townships chosen at random in the driftless area (ten in the sandstone and ten in the limestone) and twenty townships in the glaciated area (ten in the sandstone and ten in the limestone) were taken and the average value of the five leading crops per square mile was computed. This showed a difference of 23% in favor of the drift soils in the sandstone belt, and 38% in the limestone belt. Considering the sandstone and limestone belts together, the difference was about 30% in favor of the drift-covered townships. (Fig. 13.)

The three foregoing comparisons involve nearly 200 different townships in all parts of the area under investigation. So widely different is the basis of selecting the areas for comparison, that it seems certain that mere coincidences play little if any part. In all of the comparisons showing the value of crops per square mile, the results are obtained by dividing the value, in dollars, of the crops produced in a township, by the area of the township, usually 36 square miles. It will be seen that this comparison does not bring out the relative productivity of glacial and driftless soils, acre for acre, but the relative value of crops per township. A township with less productive

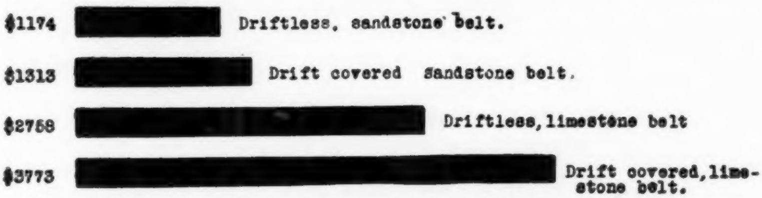


FIG. 13.—Value of 5 leading crops per square mile of total area of 40 townships—20 driftless and 20 drift-covered—taken at random.

soil, but having more of its area under cultivation, might show a larger crop value than another township where the cultivated soil was more productive, but which had a smaller acreage under cultivation.

DAIRYING AND STOCK RAISING.—But may it not be true that the driftless area, being generally more hilly, is more largely given over to dairying and the raising of live stock than is the glaciated area? And as a result may it not be that the deficiency of crops in the driftless area is offset by a higher value of farm animals?

Dairying.—Of the leading ten counties in the production of cheese, six—the first, second, fourth, seventh, ninth, and tenth in rank are in the glaciated area. The county ranking third is about half in the driftless and half in the glaciated area. The six and one-half glaciated counties produced in 1910 about 68 million pounds of cheese, or over 10 million pounds each. The three and one-half driftless counties produced 24 million pounds or less than 7 million pounds each.

Of the leading ten butter-producing counties, six—the first, second, third, fourth, fifth, and ninth in rank—are in the drift area and the other four in the driftless. The glaciated counties produced on an average $4^{1}/_{3}$ million pounds of butter in 1910, and the four driftless counties produced on an average of $3^{1}/_{2}$ million pounds each. Thus, the drift-covered counties on an average led by a margin of over 40% in the amount of cheese produced, and by about 25% in the amount of butter produced.

Farm Animals.—The total value of farm animals in five driftless counties, having the largest number of such animals, in 1910 was

slightly over 19 million dollars, and in the leading five glaciated counties it was nearly 22 million dollars, an actual difference of 14% in favor of the glaciated counties. It seems, then, that in the value of crops, of dairy products, and of farm animals, the glaciated area surpasses the driftless to a noteworthy extent.

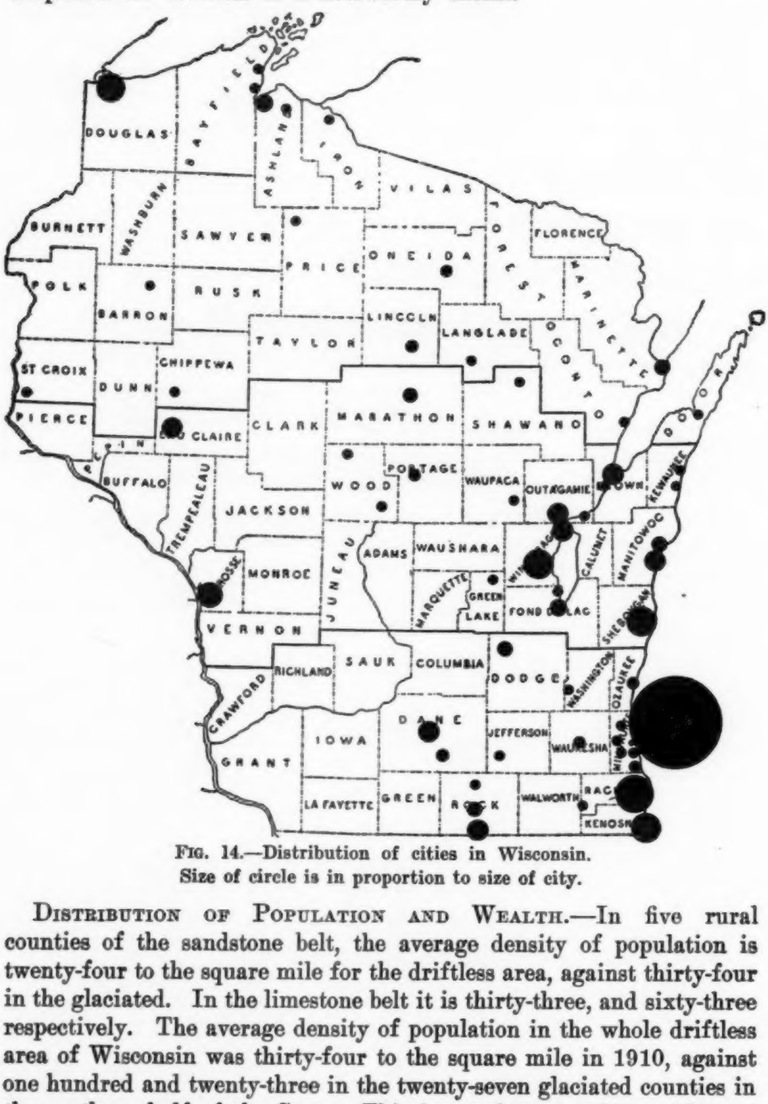


FIG. 14.—Distribution of cities in Wisconsin.
Size of circle is in proportion to size of city.

DISTRIBUTION OF POPULATION AND WEALTH.—In five rural counties of the sandstone belt, the average density of population is twenty-four to the square mile for the driftless area, against thirty-four in the glaciated. In the limestone belt it is thirty-three, and sixty-three respectively. The average density of population in the whole driftless area of Wisconsin was thirty-four to the square mile in 1910, against one hundred and twenty-three in the twenty-seven glaciated counties in the southern half of the State. This is not due to earlier settlement

in the eastern, or glaciated area, for the first rush of people into Wisconsin, as has been pointed out, was into the lead-mining region which happens to be driftless. The fact that the average density of population in the unglaciated part of the State is but little over one-fourth as great as in the other southern and central counties is largely explained by the fact that the development of industrial centers has been much greater in the southeastern quarter of the State than in the southwestern, or driftless, quarter. But why is this? Has it any connection with the glacial episode? Apparently it has, if we may regard Lake Michigan as glacier-born. Lake Michigan determined the location of Chicago and Milwaukee, and either directly or indirectly through the influence of these two cities, has stimulated the growth of the sixty other smaller industrial centers in the eastern and southeastern part of Wisconsin (Fig. 14). In the fifteen driftless counties the average assessed wealth in 1910 was $28,000,000 per county against $66,000,000 in the glaciated counties. While the above is true, it would be unwise to stress this influence of the glaciation of Wisconsin upon the distribution of wealth and population. To a very large degree that influence has been indirect, not direct.

Comparisons of Productivity Per Acre.—We have compared the agricultural wealth and productivity of the glaciated and driftless areas by square-miles, townships, counties and groups of counties, and each comparison places the advantage on the same side—on the side of the drift-covered territory. The question has already been raised whether this shows that the drift actually makes better soil or whether, by smoothing the topography, the drift mantle increases the proportion of land available for agriculture. This can be answered only by comparing the actual *productivity per acre* of the soil in various parts of the drift-covered and driftless country. For this comparison, the three best farming counties of the driftless area and three of the best glaciated counties, all in the limestone belt, were selected.

Average Number Bushels Per Acre in 1909.

Driftless Counties.	Corn.	Oats.	Barley.	Potatoes.	All Four.
Richland	35.4	34.6	25.7	120.0	215.7
Grant	35.6	33.2	26.5	101.0	196.3
Lafayette	36.3	35.0	25.6	105.0	201.9
Average	35.7	34.2	26.0	108.6	204.6
Drift Counties.					
Rock	33.2	31.4	23.0	125.0	212.6
Walworth	44.3	36.6	30.1	87.0	198.0
Jefferson	37.6	37.1	29.0	109.0	212.7
Average	38.3	35.0	27.3	107.0	207.8

A group of six contiguous counties in the sandstone area shows the following:

	Average number of bushels per acre			
Driftless Counties	Corn.	Rye.	Potatoes.	Average.
Adams, Juneau, Jackson	21.0	9.6	76.0	35.5
Drift Counties.				
Marquette, Waushara, Waupaca	25.3	11.3	107.0	47.8

From the above tables it appears that in the limestone belt:

1. The yield of corn, oats and barley was a little higher per acre, but only a little higher, in the drift soil than in the driftless.
2. The yield of potatoes was a little higher per acre, but only a little higher, in the driftless soil.
3. When all four crops are considered, the balance is slightly in favor of the drift soil, but only slightly.
4. The largest yield per acre in the case of each crop was on drift soil.

In the sandstone belt, the difference is more pronounced. In each of the three main crops, the average yield per acre is distinctly higher in the drift soil, averaging for the three crops practically $33^1/_3$ per cent.

The foregoing results are in accord with the impression which one gets from traveling through the regions in question, and is in accord with what we might expect from the known facts. The residual limestone soil of Wisconsin, like that of Kentucky or Virginia, is inherently rich and would not be much improved by the addition of the drift. The residual sandstone soil is inherently sterile and would be materially improved by the addition of drift which came from the limestone area on the east, as was true in the case of Wisconsin.

The discrepancy between two sets of results in the case of the limestone belt is significant. It will be recalled that the value of the crops grown *on an average square mile* of the glaciated portion of the limestone belt was from 23 to 40 per cent. greater than that of the crops grown on an average square mile of the driftless limestone belt, while the *average yield per acre* of the land actually in crops was only $1^1/_2$ per cent greater. This seems to prove quite conclusively that glaciation did very materially benefit the limestone belt of the State, *not chiefly by improving the quality of its soil, but by smoothing the surface and thereby increasing the amount of tillable land.* It is also deserving of note that there are few swamps and no lakes in the area whose drainage was not affected by glaciation, but many lakes and swamps were produced in the glaciated area; notwithstanding this, there is a considerably larger proportion of improved farm land in the glaciated area. This seems to indicate that notwith-

standing the swamps and lakes introduced by the glacier, the net result was to increase the proportion of land available for agriculture.

Summary of Facts Pertaining to Agriculture in the Glaciated and Driftless Areas.—1. Notwithstanding the swamps and lakes in the glaciated area, 61% is improved farm land, against 43.5% in the driftless area, a difference in favor of the glaciated area of 17½%.

2. In the fifteen driftless counties, the average value of farm lands and farm buildings is about $12,000,000 per county, against $18,000,000 in the glaciated area, a difference in favor of the latter of 50%.

3. In three typical unglaciated sandstone counties, the percentage of improved land in 1910 was 37.2, against 48.2 in three typical glaciated sandstone counties, a difference of 11% in favor of the glaciated area.

4. In three typical unglaciated limestone counties, the percentage of improved land in 1910 was 60.5, against 70.3 in the glaciated area, a difference of about 10% in favor of the glaciated counties.

5. In the counties referred to in 3 and 4 above, the glaciated sandstone area produced in 1909, 10% more per square mile, and the glaciated limestone area 31% more than the corresponding unglaciated counties.

6. In the driftless area, there are on an average over 126,000 acres per county of woodland and woodland pasture, against about 50,000 acres per county in the glaciated area. This difference is largely due to the more rugged topography of much of the driftless area.

7. Curves showing value of farm land and farm buildings in four rows of counties, extending east and west across the drift and driftless areas, all bend downward notably in the driftless counties.

8. In the case of four counties which are so crossed by the terminal moraine, that part of their respective areas is glaciated and part driftless, there was in 1905 a difference of 40% in the average value of all crops per square mile, in favor of the glaciated parts of these counties.

9. In the case of two continuous chains of townships on either side of the terminal moraine, there was in 1905 a difference in crop value of 23% in favor of the glaciated townships.

10. In the case of forty townships taken at random, the average crop value per square mile in the twenty glaciated townships exceeded that in the twenty driftless townships by about 30%.

11. Among the counties which lead in number of farm animals, and in the production of butter and cheese, there is a wide margin (from 14% to 40%) in favor of the glaciated counties.

12. In density of rural population and assessed value of property, there is a difference in favor of the glaciated area, which may be

conservatively placed at 50%, but various factors enter into the problem making accurate comparison impossible.

13. When the productivity of glacial and non-glacial soils is compared acre for acre, the difference in the limestone belt is only 1½% in favor of the glacial soil, but in the sandstone belt it is over 30%.

14. The glaciation of Wisconsin enhanced the agricultural output of the glaciated area somewhere between 20% and 40%; in the sandstone belt, mainly by improving the quality of the soil; in the limestone belt, mainly by increasing the amount of land available for agriculture. Upwards of 10,000,000 acres of this glaciated land is in the well-developed part of the State. Assuming the average value of all farm products on this area at $10.00 per acre and assuming the medium figure—30%—as the measure of the enhanced value of the land due to glaciation, then the economic result is $3 per acre or $30,000,000 annually. It seems from the results of the various lines of inquiry recorded in this paper that this sum is not too large.

In drawing the foregoing general conclusions one condition has been assumed as true, which may be called into question. It is assumed that the preglacial topography of eastern Wisconsin was as rough as is the present driftless topography, and that the preglacial sandstone and limestone soils were essentially like these soils now are in the driftless area. So far as the soils are concerned, there is little if any doubt that the assumption is justified. With respect to the preglacial topography, it has already been stated that the well records obtained in the drift-covered area by Alden and Thwaites indicate a preglacial relief approximately as great as the present average relief of the driftless area.

Economic Aspects of Glacial Lakes.—In the northern part of Wisconsin are many hundreds of lakes. In the eastern part of the State, south of the latitude of Green Bay, there are scores of lakes, varying in size from mere ponds to Lake Winnebago, whose area is over 250 square miles. Each lake covers an area of ground which otherwise might be productive farm land. The value of the land thus submerged must be charged against the lakes.

Take, for example, the chain of four lakes near Madison. The area of the largest is 9,700 acres. The average value of land in Dane County, in which these lakes are located, is $73.00 per acre. The approximate value of the land destroyed by the largest lake is $708,000, which must be charged against it. What is there to place in the credit column as an offset?

1. The charm and beauty of lakes make lake shore-lots choice building sites for residences in any city or town so fortunate as to possess a lake front. Lake-shore lots sell for several times as much as ordinary lots. The shore line of Lake Mendota, the largest of the lakes

of Madison, has a length of 22 miles, or 116,160 feet; 15,800 feet of this is in the city of Madison and is valued at considerably above $100 per foot of water front. Beyond the city limits the value of entire farms with a lake shore, as fixed by actual sales, averages $1,200 an acre, or more than 16 times the value of farm land in the county at large. A narrow ring of land around Lake Geneva, Wisconsin, would sell to-day for more than an area of farm land equal to the size of the lake. Around some smaller lakes like Oconomowoc, the ring of lake shore land is worth many times as much as an area of farm land equal to that submerged by the lake. The value of fish and ice annually taken from such lakes reaches many thousands of dollars; and in frequent cases, the value of a city's water supply must be added.

Lakes equalize the flow of streams and thus act to the benefit of down-stream water power, as in the conspicuous case of Lake Winnebago in the Fox River. The maximum flow of the lower Fox in second feet in 1903 was about eight times the minimum, while in the case of the Black River, for example, it was twenty-two times. Along the lower Fox, upwards of 32,000 horsepower is developed, more than on any other river in the State. This valley forms one of the leading paper-making districts of the United States, a fact due largely to the waterpower. The larger lakes, especially Michigan and Superior, modify climate and favor the growing of fruits, and fruit lands are more valuable than ordinary farm lands. The two most successful fruit-producing areas of Wisconsin are Door peninsula, extending into Lake Michigan, and Bayfield peninsula, extending into Lake Superior. Cherry orchards in Door County produce as high as $700 worth of fruit per acre. When all of the credit items are put together it seems that they must exceed the debit item—the loss of the submerged land. Of course the aesthetic value and pleasure-yielding value of the lakes can not be measured in dollars. I think it is safe to say that the people of Wisconsin regard their lakes as an asset, not as a liability.

Water Power.—In 1912 the developed waterpower of Wisconsin was placed at approximately 180,000 horsepower. Nearly all of this was in the glaciated area of the State and, for the most part, owed its existence to rapids and falls of glacial origin. In the southeastern quarter of the State, the drift has so clogged the streams that water power sites are very rare. In the northern half of the State, where greater elevation gives the rivers a higher gradient, waterpower sites are numerous and investigations by the engineers of the State Geological Survey place the available waterpower at a million horsepower. It is computed that the annual saving represented by waterpower over steam power in Wisconsin is about $20.00 per horse-

power. On the basis of 180,000 horsepower now developed in the State, the annual saving would amount to $3,600,000, but it is impossible to state how much of the waterpower already developed or to be developed in the State is actually attributable to glaciation. Relatively little power is developed in the driftless area, and relatively little can be profitably developed; the streams have so perfectly graded their courses that a low, fairly uniform gradient is established, and this is unfavorable to the utilization of waterpower. On the other hand, it happens that the glaciers over-rode that part of the State which might be expected to have afforded most waterpower sites, even without glaciation, namely the northern part.

A basis of comparison is afforded, however, by the Black River and the upper Wisconsin, both flowing in the same kind of rock, flowing in parallel courses and emptying into the same river, the Mississippi. The Black flows 77 miles in the pre-Cambrian area; its watershed is wholly outside the region reached by the Wisconsin ice sheet. The drainage basin has reached a stage of some maturity for lakes are wholly wanting. In the seventy-seven miles, its average fall per mile of 5.8 feet is nearly twice the *average* of the upper Wisconsin (3.1 feet), yet so well is its channel graded that there is but one place where the fall averages as high as nineteen feet per mile. Contrast with this the upper Wisconsin, whose average fall per mile is less than that of the Black but whose course has been more interfered with by glacial deposits. In sixty-six miles there are three places where the fall reaches 40, 47, and 55.6 feet per mile, respectively. It is evident that a river of the latter type, having much of its fall concentrated at a few points is superior for waterpower purposes to a river with even a higher *average* gradient, but having its fall more uniformly distributed throughout its course.

Manifestly, anything like an accurate estimate of the economic value of glacier-born waterpower in Wisconsin is out of the question. But, assuming that three-fourths of the power already developed is due to the rejuvenation of streams by glaciation, the amount will be 135,000 horsepower. The State Geological Survey's engineers place the annual saving at $20.00 per horsepower, making a total annual saving of $2,700,000. The actual value to the State does not end with the saving effected, for some important industries—particularly the making of paper and pulp—would not have been located in the State but for the available waterpower. The product of this single industry amounts to thirty million dollars a year. There is no desire to make inflated claims regarding the importance of this item to the State. The value of glacier-born waterpower, however, is real and it is considerable, certainly measured by several millions of dollars annually.

Conclusion.—In making the studies reported in this paper, the writer had no preconceived notions which he wished to prove. If, after making the thoroughgoing comparisons which were made, the results had indicated that the glaciation of Wisconsin had proved to be an injury to the State, they would have been recorded just as willingly as they have been with the present outcome. Effort has been made to get at facts, nothing else. It turns out that the findings are in accord with those reported from similar investigations in some other States, although I am not acquainted with any published reports of inquiries which have attacked the problem from so many different angles as has this one.

If the actual agricultural conditions in the driftless and glaciated areas were not markedly different and were not markedly better in the glaciated area, then it is not conceivable that in every one of the numerous comparisons made, the balance should always be found on one side. In such a series of comparisons, there is only one way in which the glaciated area can always appear to be agriculturally superior, and that is by actually being superior. No such unbroken series of findings, always indicating the same thing, is conceivable, except on the assumption that the facts and the findings are in substantial agreement.

It may be held that this investigation does not prove that the eastern part of southern Wisconsin has been greatly improved for agricultural purposes by glaciation, since we have no means of accurately knowing what the preglacial conditions in *that part of the State* were. But the investigation does prove that the glaciated part of southern Wisconsin is *now* agriculturally superior to the driftless part, and this carries with it a strong presumption that glaciation is the main cause of the superiority. The following facts appear to be established:

1. That the sandstone soils were improved in productivity by the admixture of drift which they received.

2. That the limestone belt was materially benefited by glaciation, more, however, through the smoothing of the topography than through actual improvement of the soil.

3. That, notwithstanding the swamps introduced, a considerably larger proportion of the glaciated than of the driftless area is suited to the production of crops.

4. That even dairying and stock raising are more extensively, not less extensively, practiced in the glaciated area than in the driftless.

5. That the superiority of the glaciated area is substantiated by the fact that the value of farm land is materially higher both east and west of the driftless area than in it.

If it is true that in preglacial time the eastern part of southern Wisconsin was essentially like the western part, as its underlying

rocks suggest, then it follows that glaciation has benefited the agricultural interests of that part of the State to the extent of something like $30,000,000 annually, though this is only an estimate based upon the average showing made by a variety of comparisons; $30,000,000 capitalized at 5% amounts to $600,000,000.

There seems to be satisfactory evidence that the lakes and water-power of glacial origin are a net economic gain of at least a few millions, and perhaps many millions, of dollars annually, and this does not include the economic benefits to the State arising from the presence on its borders of Lake Superior and Lake Michigan, benefits of first magnitude but manifestly difficult to evaluate.

Condensed Summary of Comparisons Between Glaciated and Driftless Portions of Wisconsin

Comparison of Per cent of Improved Lands.—Twelve typical counties, 6 sandstone and 6 limestone, excess in favor of drift, 10½%.

Comparison of Crop Values per Square Mile of Total Area.—Excess in favor of drift, in sandstone belt, 10%; in limestone belt, 31%.

Comparison in Per cent of Uncleared Land (southern half of State.)—In driftless area, 27%; in drift area, 11%.

Comparison of Crop Values per Square Mile in Four Counties Crossed by the Terminal Moraine.—Sandstone, average value all crops per square mile, drift, $2,776; driftless,, $1,968. Limestone, average value all crops per square mile, drift, $3,828; driftless, $2,690. Excess in favor of drift of 40%.

Comparison of Crop Values in Two Chains of Townships, one on each side of the terminal moraine.—Excess in favor of drift, in sandstone belt, 11%; in limestone belt, 36%.

Comparison of Crop Values per Square Mile in Forty Townships Chosen at Random.—Excess in favor of drift, in sandstone belt, 23%; in limestone belt, 38%.

The foregoing crop-value comparisons involve 200 townships scattered through 40 counties.

Comparisons in Dairying and Stock Raising.—Of the leading ten counties in the production of cheese, Nos. 1, 2, 4, 7, 9, 10 in rank are drift-covered; Nos. 5, 6, 8 are driftless; No. 3 is half drift-covered.

Average production of cheese per county, drift, 10,000,000 lbs.; driftless, 7,000,000 lbs.

Of the leading ten counties in the production of butter, Nos. 1, 2, 3, 4, 5, 9 in rank are drift-covered; Nos. 6, 7, 8, 10 are driftless.

Average production of butter per county, drift, $4^1/_3$ million lbs.; driftless, $3^1/_2$ million lbs.

Excess in favor of drift, cheese, 40%; butter, 25%.

In the number of all farm animals, excess in favor of drift counties, **14%.**

Productivity of the Soil.—Average of four principal crops, corn, oats, barley, potatoes:

	Bushels Per Acre. *Sandstone.*	*Limestone.*
Drift	47.8 bu.	52.0 bu.
Driftless	35.5 bu.	51.1 bu.
Excess	12.3 bu.=33%	.9 bu.=2—%

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THE FINAL REPORT OF THE NATIONAL WATERWAYS COMMISSION*

ROBERT M. BROWN

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Character of the Report.—The final report of the National Waterways Commission is one of the most important documents on our waterways that has been issued. There is no doubt that the solution of our transportation problems, in so far at least as the water courses are concerned, has been delayed by stubbornness on the part of individuals and associations in making their special hobbies the pivotal matter of the situation. To some degree the question has become a controversy and this has assumed too much the aspect of a political campaign with vociferations, platforms and slogans. Such a state of affairs is deplorable because the very complexity of the task of inland waterways ought to summon the leaders in this field of endeavor to a broad policy of consideration for every project that has a degree of plausibility. There will be differences of opinions and inevitably widely different remedies will be offered, but these differences are not going to be settled by forensic display. So it is refreshing to read a report where due weight is given to every intelligent opinion and where the discussion is apparently without bias. The two main issues which have distressed waterway conventions are the desired depth of water to be attained in the Mississippi River, the main artery of the

* The Final Report of the National Waterways Commission. Senate Document No. 469, 62d Congress, 2d Session. Final Report of 62 pages. 9 appendices, with a total of 579 pages.

Government Printing Office, Washington, 1912.

The National Waterways Commission was created by Act of Congress of March 3, 1909. The Commission consisted of twelve members of the Senate and House of Representatives with Theodore H. Burton as Chairman. The duty imposed upon the Commission by the Act was to investigate questions relating to water transportation and the improvement of waterways. The preliminary report was submitted to Congress in January, 1910, and the final report in March, 1912.

central portion of the country, and the practicability of reservoirs in preventing floods and in maintaining a low-water navigable channel.

Desired Depth of Water.—In the first of these, the fourteen-foot and the Lakes-to-the-Gulf advocates have been opposed to the nine-foot waterway plan of the Mississippi River Commission. The final report of the National Waterways Commission does not admit the question as one of vital importance, and the only discussion of depth is found in the Preliminary Report of this same Commission, printed as Appendix I of the Final Report, in which two points are presented: first, canals for deep draft vessels are profitable only when these canals connect navigable waters located near each other as the Welland Canal; or when a comparatively short canal will save a great sailing distance as the Panama Canal, or when a large city is situated within easy distance of the coast as in the case of Manchester, England: and, second, the weight of evidence favors, in general, open river navigation to a lock and dam or canalized navigation on the ground of economy. At the same time, it is recognized that if a growth of traffic should eventually be realized, thorough regularization or canalization may be a just demand.

The Reservoir System.—The second point of controversy centers about the reservoir system of flood prevention and low water control. The Report considers this method of stream regulation at some length. The point is clearly made that a reservoir system built primarily for flood prevention will not be practicable as a means of aiding navigation or power development. If it is desired to use the reservoirs for all three functions, it will be necessary to have the reservoir large enough to impound the requisite sum volume of water demanded by each project if acting separately. There is cited the case of the proposed reservoir on the Genesee River. This contract provides for a dam 152 feet high and the volume of water is figured sufficient for all purposes in the scheme of the promoters. The first 32 feet of water are to be held for infrequent use, the next 45 feet of water are intended to raise the water stage during the low water season, the next 55 feet are for power development and of the remaining 20 feet, 15 are planned to lower the flood level and 5 are held in reserve for extreme floods. At the end of the flood season, this top water will be drained off to the level of the water for power development, 132 feet. Such a policy if applied to the Mississippi would probably mean a cost too great in comparison to the protection it would insure. It is a reasonable position to take that the reservoirs on the Ohio River which are proposed for the improvement of navigation cannot be of service, except incidentally, for flood protection and power development, and the theory so persistently advanced that the reservoir system which will give adequate security from overflow of levees will pay their way through the

sale of power cannot longer be reasonably entertained. The conclusions of the Commission on this point are stated carefully, although they leave the question still unsettled. This is a wise policy as much of the answer must be based on experimentation, and this state and municipal governments are beginning to undertake. They do not unreservedly recommend reservoirs, but they do look in the direction of this method of control in the proper time. Their creed is somewhat as follows:

1. The necessity of controlling floods increases with the development of the country. This is not new nor profound, but it is a basal fact in the reservoir scheme because the interest of the cost of the plant must be met by the profits of the protected areas.
2. The using of storage reservoirs becomes more practicable where the value liable to damage is great. This is a paraphrase of the first. The Commission adds that this condition has been attained on some streams.
3. This conclusion states that the Commission does not know on what streams the construction of reservoirs would result in benefits commensurate with the cost.
4. The Federal Government has no constitutional authority to engage in works intended primarily for flood prevention or power development. In this statement there seems to be implied that reservoirs can be built to aid navigation only. Thus in the case of the Genesee River dam of 152 feet, under the charge of the water supply Commission of New York State, the 55 feet for power development would have to be eliminated if it was a Federal contract reducing the height to 97 feet and possibly the 20 foot for flood catchment which would make a still further reduction to 77 feet, or about one-half the proposed height.

Two more conclusions which point out the lines of future investigation are listed. It will be seen that while the Commission appear to be perfectly satisfied concerning the practicability of reservoirs in stream regulation, they hesitate to say that the time is ripe for the building of them on any particular stream. Yet notwithstanding the uncertainty of mind which is stamped on the formal conclusions of the Commission, the entire discussion of the reservoir system is valuable and a contribution.

Influence of Forestation upon Navigation and Floods.—Another subject covered in this Report is the influence of forestation upon navigation and flood prevention, concerning which there are many conflicting opinions in print. In this as in the other lines, the Commission have given an impartial review of the discussion and have reached certain conclusions which, as one might expect, are much more moderate

than the views of the leaders of the controversy over forest influences. No universal law of influence of forests upon precipitation, run-off and erosion is found. The variations of rainfall, slope and porosity of the soil are such that on one stream the effects of forests may be beneficial to stream flow and mitigate floods, while on another the opposite results may be experienced. Moreover, the Commission is convinced that in no case can forests be relied upon to prevent floods or low water conditions, nor will they take the place of storage reservoirs in securing a uniform stream flow. The main benefit of the forest cover lies in the prevention of erosion; and, inasmuch as this conclusion has been reached, there seems to be no reason why forests at headwaters of streams should not be removed if the land is desirable for agriculture providing a proper vegetation cover is given the land or some suitable manipulation of land slopes is undertaken in order to prevent erosion.

The Railway Control.—The depth of the Mississippi waterway and the reservoir system of control are subjects which have stirred deeply the believers in inland water routes; the effects of deforestation on stream flow is a question that has been discussed, somewhat bitterly I fear, as a concomitant but not as a main issue, but the lack of co-operation between the railways and the waterways is after all the sore spot in our waterway troubles. In two directions, the railroads have blocked the increased use of waterways; first, by the control of water terminals, and, second, by their refusal to co-operate by prorating or otherwise in water shipments. The Commission believes that the proper solution of the terminal question is most vital to the future of water transportation. The railroads own or control a large proportion of the water fronts which are held in a manner adverse to water traffic either by demands for unreasonable terminal charges or by preventing the development of water frontage. For the solution of the problem, the Commission proposes that the state or municipal officials condemn such property for public use. The co-operation of railway and waterway is a more difficult task because there are so many ways open by which, within the letter of the law, a railway company may stifle the intent of the law. There is nothing ethically wrong in lowering rates in competition providing these rates are neither discriminating nor temporary. The shipper or the buyer is interested in waterways only as they reduce the marketable cost of his wares, and consequently he enjoys competition rather than harmony. The tendency of large railroads to combine and the control of railways over waterways are, to be sure, a move towards harmony and co-operation but the elimination of competition establishes a monopoly in a branch of the public service which renders them a subject of control by the Federal Government. The Commission recommends that waterways be under the control of the Interstate

Commerce Commission and be made common carriers—a move which would allow the Commission to establish a connection between rail and water lines by requiring joint rates.

New Canals Proposed.—In addition to the subjects discussed in this review, the United States National Waterways Commission advises the construction of the proposed canal between Lake Erie and the Ohio River near Pittsburgh, and pronounces entirely feasible both the Lake Erie-Lake Michigan artificial waterway and the Anacostia-Chesapeake canal.

The larger discussions of a number of the topics by experts are collected as appendices. Here may be found valuable papers on storage reservoirs by Leighton, Follansbee and Bixby, on forest influences with an extensive bibliography by Zon, on legal aspects by Mooney and on a comparison of American and European waterways by Merchant. Altogether the volume of 580 pages contains a vast fund of information and the pages devoted to the Final Report proper offer a safe and valuable basis on which to found any study of the waterway problem.

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MEMOIR OF RALPH STOCKMAN TARR

ALBERT PERRY BRIGHAM

Ralph Stockman Tarr was born January 15, 1864, in Gloucester, Massachusetts. He died, after a brief illness, at his home in Ithaca, March 21, 1912, being a little more than forty-eight years of age. In Gloucester his boyhood and youth were passed. What the influence of early environment must have contributed to the main currents of his life was told by one of his fellow teachers, at the funeral service in Sage Chapel, on the campus where he had wrought for twenty years. "For a student of geography few places could have given better preparation than the busy Gloucester of his youth. It was not yet the day of the steam trawler, creeping sullenly in to swell the profits of a trust; instead, fleets of deep-laden bankers, the nested dories shining from their decks, crowded on all sail in the homeward race. High sparred barques discharged salt from Portugal, and handy schooners sailed out past Norman's Woe with cod for Barbadoes and Funchal. The mystery of earth's space, the romance of far flung trade, brooded over the little port."

After he had passed away there was found a writing, not before known to exist. It was written in a small black-bound note book of the United States Geological Survey, in a clear but swift-running hand. It was a short sketch of his early life, made apparently at a single sitting, on the Nugsuak Peninsula, Greenland, September 6, 1906. In this short but absorbing story of experience, he tells the ventures and struggles through which he passed from 1881, a youth of seventeen, until he was far into the midstream of his career, fifteen years later. To follow the lines of this self-revelation, made without reserve but with absolute simplicity, has been to the writer of this memorial, a sacred privilege.

On graduation from the high school in 1881, Tarr's interest in science led him to enter the summer school of the Peabody Academy at Salem. He was unable to continue there, but a talk with one of his teachers planted the impulse to go to college. He determined upon the Lawrence Scientific School and entered at Cambridge in the autumn. He made daily trips over the thirty miles between Gloucester and Cambridge, rising at 5:30 for the 6:15 train, reaching home at eight o'clock in the evening, whose later hours were filled with study. It is no wonder that by June, as he says, he was tired out and somewhat discouraged.

In the summer came an opportunity to assist Professor Alpheus Hyatt in dredging and to study invertebrates in his private laboratory. The following autumn he spent a short time at Wood's Holl, dredging with Professor Baird and then went to the Smithsonian Institution in Washington, where he was given work through the winter and spring. In the summer of 1883 he was at Wood's Holl again, dredging, and beginning to write articles for the *New York Sun, Nature,* and other papers, on deep sea life. This new work offered a further means of self-support and gave him a training in expression which was to be used throughout his life. *Science, Forest and Stream,* the *Presbyterian Observer,* the *Congregationalist, Boston Transcript, Leslie's Monthly* and many other papers received his contributions during this period. His first original paper, on the crawfish, appeared at this time in *Nature.*

At the end of the year he resigned his place at the Smithsonian and returned to Gloucester. In Washington he had found friendships in cultivated homes, which helped to carry him through the years of change and youthful struggle while he was finding himself and driving on, without seeing his way, toward his life work. In the summer of 1884 he made a trip up the Saguenay and into the woods. This was an early expression of his great love for travel and for widening his field of observation. In the fall of 1884 he went back to college, this time living at Cambridge. New opportunity to earn his way and a great impulse in a new realm of study thus came with the acquaintance of Professor Shaler.

Interrupting college with a long and disappointing experience on a western ranch, he returned to Shaler and geology in 1887. His western sojourn had increased his interest in the science and his counsellor and friend helped him to realize a purpose, which, after many vicissitudes, was now shaping itself to grim determination. He now accomplished much work on the geology of Cape Ann, a problem which he says was much too big for his experience. It may in truth be said, however, that the report on that region published in the Ninth Annual Report of the United States Geological Survey is substantially Tarr's work.

The next year he was one of a group of geological students, numbering Whittle, Woodworth, Penrose, Cobb, Ladd, Foerste, Dodge, Collie, and others, an association marked by true fellowship and progress in science. He followed with summer work under Shaler and developed his interest in physical geography and glacial geology. In the fall of 1888 college work was again interrupted by an appointment to the Arid Land Survey. He went to New Mexico, learned stream gauging and the use of meteorological instruments and was promoted from the position of "skilled laborer" to that of hydro-

grapher. Service in Montana followed, and later he spent a large part of 1890 as a member of the Geological Survey of Texas.

Returning to Cambridge he became an assistant to Shaler, continuing his studies under Professors Shaler, Davis and Wolff and receiving his college degree in 1891. He was appointed to the professorship of geology in the University of South Dakota, but having a position already under Wolff in the Archaean Division of the national survey, he declined the call to the west. In the spring of 1892 he was married to Miss Kate Story of Gloucester, and received a temporary appointment at Cornell. There is ample reason to believe that Professor Dana desired Tarr to succeed him in the Yale chair, but he was not successful in bringing about this end. In 1894 Tarr was appointed to the Cornell chair for three years. In 1895 he published his Elementary Physical Geography and accomplished his work in the Chautauqua grape belt. In 1896, worn with many tasks, he spent a short period of rest in the Bermudas, and returned to organize the Cornell expedition to Greenland. This was successfully carried out and added to his experience and productive observation.

Thence to the end, his life was closely linked to Cornell University. His labors as teacher, author, investigator and traveler follow one another with bewildering rapidity. Not best in the way of chronology, can these activities be set forth. The order of events does not count much in a great life, for such a life expresses character and truth, realities far beyond the hampering bounds of time.

Professor Tarr never lost sight of his opportunities as an investigator. He had a restless passion for new truth, which ran side by side with his desire to acquire and interpret the old. In his search he showed contempt for weariness, devoted himself to rapid and almost ceaseless work and took little account of personal danger.

He at once made himself at home in the region about Ithaca. The field was rich in physiographic and glacial problems, and he took up the origin of the Finger Lake basins, the history of the drainage, the evidences of the glacial Finger Lakes, the distribution of the local terminal moraines, and the characteristics of the post-glacial gorges. In more recent years he executed a detailed survey of the Ithaca and seven neighboring quadrangles, and his results appear in the Watkins Glen-Catatonk folio of the United States Geological Survey. This is one of the very few regions in New York whose glacial phenomena have received full areal study and mapping.

Professor Tarr became interested in Alaskan work and spent there the summers of 1905 and 1906 under the National Survey. In 1909 and 1911 he conducted parties in Alaska under the auspices of the National Geographic Society. In 1909 he published, as Professional Paper 64, the Physiography and Glacial Geology of the Yakutat

Bay Region, Alaska. With Martin as co-author he published "Earthquakes at Yakutat Bay, Alaska, in September, 1899." This appeared as Professional Paper 69 of the Survey. The National Geographic Society now has in course of publication a volume on Alaskan Glacier Studies, which deals with the research work in 1909 and 1911 and also embodies the work of Martin in 1910. He also left the nearly completed manuscript of a College Physiography, a production of his maturity, which is now being edited and prepared for publication. Members of the Association recall the vigor, the comprehensive interpretation and the compelling interest of his paper on "Glaciers and Glaciation in Alaska," which he offered as his presidential address at the Washington meeting.

The Greenland work was the basis of several papers, and the years 1901, 1902, 1909 and 1910 were marked by long sojourns in Europe, with many field trips and much active study. During his last year abroad he gratified his love of work in the far north by going to Spitzbergen with members of the Geological Congress. He visited Panama in 1907. Not long before the time of his death he was making plans for a summer in Newfoundland, where he had long desired to study the features of glaciation.

He was positive in opinion but considerate of the views of others. His paper on the theory of the peneplain showed these qualities. Professor Davis in his rejoinder, while controverting Tarr's opinions, recognized the paper as an example of fair and temperate discussion. As time went on he developed a larger and riper interest in human geography, as is shown by many of his papers, especially by some which were offered for the programs of this Association.

His life shows what a great teacher does as a fountain of instruction, inspiration, co-operation and friendship. He loved to acknowledge his debt to Shaler and he exhibited in his own teaching many of the traits of his early master in the earth sciences. He had broad interest in man and nature and he brought the youth and nature together, confident of the result, heeding little the nice precisions of any particular method of approaching a problem. He was able to see beyond the young investigator's crudities and errors, to preserve the young man's respect for his intellectual self and allow him to evolve his own ways of working without hindrance.

A multitude felt his influence at Cornell University. There are to-day many teachers of Geology and Geography whose scientific father he was, and I have never seen one who did not pay credit to the vitality of his teaching and the purity and nobility of his manhood.* There was an atmosphere of geographic interest in which his

* Among Tarr's former students may be named the following: J. A. Bonsteel, U. S. Bureau of Soils; B. S. Butler, U. S. Geological Survey; S. P. Carll, economic

students lived and worked. They found it in him, in his laboratories, in the field and within the ever open doors of a lovely and hospitable home. The thorns that beset his early paths made him sympathize with the hardships and baffled progress of others.

Among his students were many teachers who came to the University for the summer courses. Several years of association with him in this work first brought the writer of this sketch into an appreciation of his sympathetic power as a teacher.

He took much interest in gathering and acquiring the materials of instruction. He fitted others to do the details of this work, and was always surrounded by a group of efficient student assistants. He never allowed himself to be submerged by the numberless material arrangements which tempt and engross some teachers of science. He recognized more than most teachers the necessity of field work, and both his summer courses and the regular courses were securely buttressed by this kind of study.

Professor Tarr produced in rapid succession a series of most important and successful text books. His first ventures were in the field of economic and of high school geology. Next came the first of his physical geographies, which was a major contribution to the pedagogy of geography, and which, in the field of high school work, was the pioneer in making the new geography available. The book had an awakening freshness of treatment and wrought large results in its field. It was followed by later texts on the same subject, and by the writing, in coöperation with Professor McMurry, of one of the leading series of elementary geographies in America. He was fertile in devising helps to accompany his various texts, and there was cut off by his death an attempt at the problems of experimental geography, which promised good not only to teachers but to the growth of the science itself.

A series of articles on the geography of New York state was published in the Bulletin of the American Geographical Society and later embodied in a volume. His pen was fertile in articles for geographical journals, and of the one already mentioned as well as of the Journal of Geography he was an associate editor. He also

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geologist; Frank Carney, Denison University; William Lockhead, Ontario Agricultural College; G. D. Hubbard, Oberlin College; M. T. Iorns, University of Texas; F. V. Emerson, University of Louisiana; J. O. Martin, U. S. Bureau of Soils; G. C. Matson, U. S. Geological Survey; Lawrence Martin, University of Wisconsin; F. S. Mills, geologist; W. E. McCourt, Washington University; Mr. Marvin, of Peary's North Pole party; F. N. Meeker, U. S. Bureau of Soils; C. L. Mills, U. S. Weather Bureau; E. M. Kindle, Canadian Geological Survey; J. L. Rich, University of Illinois; R. P. Tarr, Northern Pacific Railway; O. D. von Engeln, Cornell University; T. L. Watson, University of Virginia; R. H. Whitbeck, University of Wisconsin.

contributed to Johnson's Encyclopedia, the International Encyclopedia and to the last edition of the Encyclopedia Britannica.

Professor Tarr was a fellow of the Geological Society of America, a constituent member of the Association of American Geographers, a member of the Sigma Xi, of the Seismological Society of America, and a foreign correspondent of the Geological Society of London. He served on the International Glacial Committee and shortly before his death was elected a corresponding member of the Royal Geographical Society of Vienna. The news of this recognition was not received until he had passed away.

To the Association of American Geographers he gave loyal and unfailing service. He was a Councillor for two terms and served as first vice-president in 1907. In this year, following the death of Professor Heilprin, he was acting president and presided at the Chicago meeting. At the same time, owing to the absence of the Secretary, he performed the duties of that office also for several weeks during the preparation of the program. He presented papers with great regularity and attended every meeting except that of 1909, when he was absent in Europe. It is fresh in our memory that he was President of the Association in 1911.

His career was strengthened by a happy home life. It was tempered by sorrows in the loss of two of his four children, but dominated by good cheer. Success did not elate him, for he modestly made each stage of life the platform for new achievements.

His body rests in a little cemetery upon the terrace of an elevated delta of one of the former glacial lakes which preceded Lake Cayuga. His grave is fittingly marked by a glacial boulder, a striated erratic of granite, transported long ago from Labrador or the Adirondacks by the continental glacier and thus made ready to mark forever the resting place of one who worked long and well to interpret the records of glacial action.

After all, it is his personality which we miss most and honor most. Possessed by powerful early impulse, with purpose vaguely defined, he entered every avenue that opened in the great field and at last found the broad highway for his steps. Mental turmoil and financial struggle he compelled to an issue in clear purpose and in material and intellectual triumph. His basal quality was sincerity. He was fairness personified. He was incapable of envy or of any mean motive or act. He had profound contempt for indirectness and lived in broad charity. He would not make a harsh utterance in the face of personal injury, yet he was capable of blazing indignation and of withering contempt for all that was beneath the standards of a man. To all who loved him, and they are many, the loss is irreparable, but memory is fragrant and the heritage of his life is permanent.

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MEMOIR OF ABBOTT LAWRENCE ROTCH

ROBERT DE COURCY WARD

Abbott Lawrence Rotch was born in Boston, January 6, 1861. He was graduated from the Massachusetts Institute of Technology (S.B.) in 1884. From 1888 to 1891, and again from 1902 to 1906, he held the appointment of assistant in meteorology at Harvard, a position which involved no teaching and in which no salary was paid. In 1906 he was appointed professor of meteorology, an honor which he prized very highly, and which gave him the position on the teaching staff of the university to which he was in every way fully entitled. He was the first professor of meteorology who has occupied that position at Harvard, and he served in this professorship without pay.

In the year 1908-09 he generously put the splendid instrumental equipment and library of Blue Hill Observatory at the service of the university, by offering a research course to students who were competent to carry on investigations in advanced meteorology. This gave Harvard a position wholly unique among the universities of the United States. To his work as instructor Professor Rotch gladly gave of his time and of his means. He fully realized the unusual advantages which he was enabled to offer those students who were devoting themselves to the science of meteorology, and the experience of the men who had the privilege of his advice and help in the work at Blue Hill shows clearly how much they profited by this opportunity. Only a short time before his death he had expressed the wish to bring about a still closer connection, for purposes of instruction, between the university and Blue Hill Observatory.

While thus planning still further usefulness for his observatory; in the midst of a life singularly active, Professor Rotch died suddenly in Boston on April 7, 1912, in the fifty-second year of his age.

Professor Rotch early developed that absorbing interest in meteorology which caused him to devote his life to the advancement of that science. Realizing the need of an institution which could be devoted to the collection of meteorological observations, and to meteorological research, free from any entanglements, he established, in 1885, Blue Hill Observatory. This observatory he not only equipped and maintained until his death, but he made provision in his will for having the work there carried on without a break. Blue Hill Observatory is to-day one of the few private meteorological observatories in the world, and there is not one which is better equipped. In fact, it is

probably safe to say that there is no private scientific establishment which is better known for the high standard of its work. The Blue Hill Observatory was, with one exception, the first in this country to be equipped with self-recording instruments, and it is to-day one of the comparatively few in the world where nearly every meteorological element is continuously recorded.

It was one of Professor Rotch's most striking characteristics that he never neglected any opportunity which might help him to keep his observatory not only abreast of the times but ahead of the times. He thought nothing of the time and the expense of taking a trip to Europe in order to attend some scientific meeting, if he believed, as he most firmly did, that he might by so doing gain inspiration and new ideas. Few scientific men are so regular in their attendance at congresses and meetings; few contribute so much that is new, or gain as much inspiration as he did at such gatherings. The list of scientific bodies of which he was a member is a long one, but every one of them gained much from his membership and from his presence at its meetings. He was regular in his attendance; ready to contribute papers; modest in his estimate of the importance of his own work; generous in his appreciation of the work of others; always ready with a word of sympathy, or encouragement, or fellowship.

We, of the Association of American Geographers, owe him much. A year ago he was with us, a helpful, energetic, enthusiastic fellow-worker. To-day his place is vacant. We miss his cheering presence, his active coöperation, his unflagging interest.

The productivity of his observatory has been remarkable. The study of cloud heights, velocities, movements, and methods of formation, at Blue Hill, was one of the most complete investigations of the kind ever undertaken. The first series of measurements in America of the height and velocity of clouds, by trigonometrical and other methods, was made at Blue Hill in 1890-91.

It was at Blue Hill that the modern methods of sounding the air by means of self-recording instruments lifted by kites were first developed and effectively put into practise (1894).

It was Rotch who, in 1901, during a voyage across the Atlantic, first obtained meteorological observations by means of kites flown from the deck of a moving steamer, thus indicating the feasibility of a new way of securing information concerning the conditions of the free air over oceans and lakes. It was Rotch who, in 1904, secured the first meteorological observations by means of sounding balloons from heights of 5 to 10 miles over the American continent. In 1905-06 he joined his colleague, Teisserenc de Bort, in fitting out and taking part in an expedition to explore the tropical atmosphere over the Atlantic Ocean by means of kites and pilot balloons, an undertaking

which resulted in the collection of important data regarding the temperatures and movements of the upper air, and especially concerning the existence of the anti-trades. But Rotch was not content with sending up kites and balloons. His enthusiasm in the study of the free air, and his desire to visit the mountain observatories of the world, led him to become a mountain climber of no mean ability. He ascended to the summit of Mont Blanc at least five times, and in South America and elsewhere he himself made meteorological observations at considerable altitudes on mountains, and carefully observed the physiological effects of the diminished pressure. He also took part in several balloon ascents. He was a member of more than one solar eclipse expedition. His studies of eclipse meteorology are among the most complete which have been made. Among his many contributions to the advancement of meteorology must also be mentioned his invention of an instrument for determining the true direction and velocity of the wind at sea.

Professor Rotch was naturally intensely interested in the recent rapid development of aeronautics. His earlier training, and his untiring zeal in the exploration of the upper air, combined to give him this interest. He turned his attention largely in that direction of late years. It was characteristic of him that, not content with the mere collection of data, and with investigations of theoretical interest, he always strove to make these results of practical use. Thus, soon after the establishment of his observatory, the issue of local weather forecasts was begun, and one of the last things which he published (in association with Mr. A. H. Palmer) was a set of "Charts of the Atmosphere for Aeronauts and Aviators" (1911), a pioneer work, embodying many of the results of observations made at Blue Hill in a practical form for the use of airmen.

Professor Rotch's list of published papers and books comprises 183 titles. These cover a wide range of subjects, by no means strictly confined to meteorology, and show most emphatically how varied were their author's interests; how extended was his reading; how alert and progressive he was in all he undertook. These 183 titles in themselves furnish a satisfactory outline of the development of meteorological science during the past 25 years. In addition to the "Charts of the Atmosphere" just referred to, he published two other books, "Sounding the Ocean of Air," (1900) and "The Conquest of the Air" (1909).

He was a pioneer who blazed new trails in a new science; an investigator, whose name is known wherever meteorological work is done; a loyal teacher who served without salary; a generous benefactor who left to the university an enduring monument of his enthusiasm and untiring devotion to the science which he himself did so much

to advance. His life and labor have been an inspiration to his scientific colleagues everywhere, but especially to those who were most closely associated with him in the work of his observatory, and in the department of the university of whose staff he was a valued member.

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MEMOIR OF W J McGEE

N. H. DARTON

In the death of W J McGee science has been deprived of one of its most efficient workers, and mankind has lost a vigorous champion for its advancement. Had he been spared he might have had many more years of continued usefulness for he was only 59 years of age and in most respects was in fine physical and mental condition. McGee had always been a worker. He was remarkable for the universality of his interests. He was wonderfully rich in ideas, pertaining not alone to those sciences in which personally he was most interested, but also to the broader fields of general culture in which his companions might be working. A man of enthusiastic endeavor himself, he was bound to inspire enthusiasm in an honest worker in any field.

He achieved distinction in several lines of scientific work, and as an illustration of his versatility I might mention that he had a large share in the great conservation movement and was one of the principal advisors of the National Conservation Committee.

He was born on a farm in Dubuque County, Iowa, April 17th, 1853, of Irish parentage. Excepting a short attendance at the county school he was entirely self-educated. As a boy he had much to do on the farm but gave all spare time to study, and at the age of 20 had acquired the more important lines of information usually presented in schools and colleges, and had mastered sufficient law to practice in the justice's courts of his country. With some instruction from a blacksmith he became skilled in metal working mainly for the purpose of making certain agricultural implements which he invented. He also learned land surveying and at the age of 22 or 23 he began studying geology. He became so deeply engrossed with this science that he soon gave most of his time to it. It was at this period that he commenced his elaborate investigation of the superficial geology of northeastern Iowa and the preparation of the topographic base for his observations there was his first geographic work. The maps and report were finally published by the U. S. Geological Survey.

McGee's first work for the Government was on the building stones of Iowa for the 10th Census and his report was of notable excellence. From 1882 to 1893 he was geologist on the U. S. Geological Survey and during these 11 years his life was one of great activity in scien-

tific work. He traveled extensively in field work, wrote voluminously and was in close association with Director Powell in the development and administration of the survey. A summary of this work written by himself when he left the Survey and published in the 14th annual report, shows the extent and variety of his occupations in the 11 years of service. Of course it does not indicate his very great zeal and usefulness which were of incalculable value at that stage of the survey's development.

His first assignment was to assist Russell in the Lake Lahontan investigation in which he proved highly efficient. He went to Washington City in 1883 and Powell, quickly recognizing his ability, kept him there for much of the time in the following years to assist in administrative matters. He aided in perfecting cartographic methods, served on the Correlation Board and gave much attention to the classification of data available for the use of the survey. He compiled maps and reports, started the dictionary of formation names and the thesaurus of American formations, and represented the Survey at the Berlin meeting of the International Geological Congress. In connection with his study of cartographic methods McGee prepared a number of geologic maps largely for the purpose of illustrating the Survey scheme which were very useful compilations. The first of these was the geological map of the United States prepared with the assistance of Professor C. H. Hitchcock and published in 1885 in the 5th annual report. It was on the scale of 100 miles to the inch and very beautifully executed. Another edition of this map incorporating results of a large amount of new field work was issued in 1894 in part 2 of the 14th annual report.

It was McGee's instigation and zeal that led to the preparation of the large geological map of the state of New York which was the first one published since 1844. In the first stage of this work McGee and Hall made a compilation of the geology but the base was poor and the information that could be placed on the map was so fragmentary and indefinite as to location that the result was useless. With authority from the Director of the U. S. Geological Survey a new base was compiled from county maps and the writer was transferred to the state work for parts of two seasons to map boundaries and piece together the work of local observers. The map was finally published by the U. S. Geological Survey in coöperation with the state. In the course of this work I heard from James Hall warm praise of McGee's phenomenal keenness as an observer and his great ability to grasp the problems presented.

Early in his connection with the Geological Survey McGee was placed in charge of the Potomac Division of Geology which was created to study the region contiguous to the basin of Potomac River

but which was finally extended to comprise all of the middle and southern Atlantic coast province. He accomplished considerable field work himself in many portions of this area and directed the operations of a number of other investigators. Among the latter were Dr. G. H. Williams on the crystalline rocks of the Piedmont slope, Dr. J. A. Holmes, Dr. W. B. Clark, R. H. Loughridge and N. H. Darton on the Mesozoic and Cenozoic geology of the Atlantic coastal plain and Dr. E. A. Smith, L. C. Johnson and Dr. E. W. Hilgard on the formations of the Gulf region and Mississippi embayment. He also had charge of work by Hay in Kansas and of Dr. Phinney's investigation of the gas in Indiana. At the time of the Charlestown earthquake McGee was sent at once to the scene of the disaster and he obtained a large number of data used later by Dutton in his report.

McGee's principal fields of personal investigation in geology were northeastern Iowa and the Atlantic and Gulf Coastal plain. He also assisted Russell in the Lake Lahontan work and made a survey of part of Macon County, Missouri. His work in northeastern Iowa which covered an area of 20,000 square miles was done privately as already stated, before he became a member of the Geological Survey, although some supplemental work and the publication of the report were at government expense. In the Coastal Plain his observations were mainly from Maryland southward and while some of the minor details of the classification and identification of deposits may not be verified at every point, the differentiation of the Potomac, Lafayette and Columbia formations was one of the most important geologic contributions we have had. It matters but little whether or not the type locality of the Lafayette proves to be valid and that some marginal red sands are Eocene, for McGee made a master stroke in recognizing the fact that the coastal plain is covered by a wide spread mantle of littoral deposits representing Pliocene time. It was recognized over an area of 300,000 square miles and was of greatest significance in the history of the continent. McGee's first name for this formation was the Appomattox and its correlation with Lafayette was a later idea. When I began my association with McGee this formation had not been recognized north of the James River, but I found that it extended across Virginia and Maryland and some outliers remained in New Jersey. The Potomac formation has proven to comprise a group of stratigraphic units varying in range in different regions, but widely separated from the Newark group below and from the marine Cretaceous above. It included the deposit which I separated later as Magothy formation but aside from this it remains as a distinct group.

The recognition of the Columbia formation was of great significance to geography as well as to geology. It was correlated with the

earlier glacial deposits and found to cover nearly 150,000 square miles of the coastal plain. Its topography and components have most important bearing on the physiographic conditions of the early Pleistocene time in the region south of the glacier.

For many years I was intimately associated with McGee in the Geological Survey under Powell and I wish I could pay an adequate tribute to the value of his influence to me and to many other associates in those early days of the organization. He had marvelous ability to appreciate all bearings of an investigation and to make far reaching and important suggestions. His willingness to assist in guiding the policy and conduct of all lines of the survey work made him a most important member of the organization in those days. This was fully appreciated by Major Powell who brought McGee into intimate association in all administrative matters, and his genius had much to do with shaping Survey methods. He came a close personal friend of the Major's and the two spent much time together.

McGee left the survey with Major Powell at the time when the Major turned the great bureau over to the directorship of Mr. Walcott. McGee then became Powell's Chief Ethnologist in the Bureau of Ethnology, a position which opened up to him lines of investigation which were very congenial. On the death of Major Powell, in 1902, McGee continued with the bureau as acting director, but in July, 1903, on account of disagreement with S. P. Langley, Secretary of the Smithsonian, he severed his connection. This was generally regarded as a most unfortunate circumstance as undoubtedly McGee would have accomplished a very large amount of ethnological work of greatest interest and value if he had continued as director of the bureau. However, he left to accept the position of chief of the Department of Anthropology at the St. Louis Exposition where he had opportunity to make a brilliant record for administrative ability. At this exposition he presented to the public a greater variety of natives of many parts of the world than had ever been assembled before, and illustrated their natural environments, customs and products in a most instructive manner. It was one of the greatest lessons in geography that has ever been given and one that had the largest audience. When the great fair was over McGee was placed in charge of the St. Louis Public Museum project where he continued for two years till 1907, when he resigned to take up work in the Department of Agriculture as expert in charge of Soil Water investigation. This position he held until his death.

McGee made many valuable contributions to geography. In the Great Basin work he investigated the cause of the peculiar curvature of lateral moraines issuing from gorges into broad valley bottoms, some conditions of erosion by glacial ice especially in the develop-

ment of cirques, rock basins and U shaped canyons, and the law of foothill development in that region. In his study of northeastern Iowa he ascertained the conditions under which certain drift features were developed and set forth a method of determining direction of the ice flow without dependency on glacial striae. In this work also he set forth a law of land profiles applied in the driftless area, and a law of varigradation in the stream gradients. In his work on the Atlantic Coastal Plain McGee added many notable ideas to our growing science of Geomorphy, then in its infancy. He showed that geologic history could be read from topographic forms and this means was extensively used by him and by myself in unraveling the coastal plain geology. Another important mode of recognizing the formations was developed at the same time and that was by homogeny or correlation by identity of genesis . This criterion was very essential where fossils were lacking. One very important phase of this work was in the differentiation of terrace deposits and correlation of terraces which represented the same stage in the topographic development of a region. It was by this means that I mapped many areas of Lafayette and earlier Columbia deposits as well as non-fossiliferous outliers of underlying Tertiary and Cretaceous deposits. Some of these lines of work led McGee to develop a classification of geographic forms by genesis which was set forth in a paper published in the first number of the *National Geographic Magazine*. McGee's observations in lower California on his trips to Seriland and Tiberon Island afforded some very instructive facts regarding erosion conditions in arid lands. He found that sheet flood erosion was an important factor in levelling the surface and producing peneplains at various elevations above the sea. This idea has proven to be a very valuable one and has greatly simplified our conception of the topographic development of certain regions.

The paper entitled "Outlines of Hydrology" which McGee presented to the Geological Society of America in 1907 was a very valuable contribution to geography. It was a philosophic presentation of the rôle of water in nature and summarized in compact form a large amount of information. His paper on potable waters of the eastern United States published in the 14th Annual Report of the Survey was a notably complete and instructive presentation of domestic water problems. This publication was in great demand and undoubtedly had a wide influence on the development of water supplies and in guarding them from pollution. Throughout his work on the U. S. Geological Survey and later, he gave special attention to relations between geology and soils and especially the waste of soil by erosion. A large memoir on this latter subject was issued by the Department of Agriculture in 1911. It treated not only of

the conditions of soil erosion but suggested remedies which may prevent erosion and reclaim farm lands that are being damaged by it. There is now in press in that Department another publication, "Wells and Subsoil Waters," finished just before his death.

McGee always had great interest in earth crust movements and in 1894 he presented to the Geological Society a very suggestive memoir entitled "Th Extension of Uniformitarianism to Deformation." In this contribution he reviewed the criteria relating to such movements and discussed the conditions causing deformations of various kinds.

McGee gave considerable attention to Dutton's law of isostacy and showed that isostatic adjustment while sufficing to explain minor crustal oscillation is insufficient to explain the greater movements of the earth's crust. He set forth some criteria for the discrimination of two primary classes of earth movement, antecedent and consequent. In his memoir on the Gulf of Mexico as a measure of isostacy in 1892 McGee reviewed the evidences of subsidence in the Gulf region especially as indicating that the land and sea are in a state of hydrostatic equilibrium. Evidence was presented showing that in former times, however, some of the movements were cataclysmic.

Largely in connection with his work in the Bureau of Ethnology McGee achieved great distinction in Anthropology. He made many contributions to that science and devoted much time to its societies and other interests. He was president of both the American and Washington societies and was editor and contributor to the section on Anthropology in the International Encyclopedia. He was U. S. Commissioner in the International Commission of Archaeology and Ethnology, and in 1904 he was senior speaker in the World's Congress of Arts and Sciences. One of his most notable pieces of work while on the Bureau of Ethnology was an exploration of Tiburon Island in the Gulf of California. This island is inhabited by savages who had never been investigated before and the expedition which was a highly perilous one, afforded a large number of interesting and novel data. Another important item of his work in Anthropology was the formulation of principles relating to geologic evidence of human antiquity.

Probably McGee's most notable service to humanity was the prominent part which he had in the great movement for the conservation of our natural resources. He was one of the fathers of this movement and exerted very powerful influence in its growth and promulgation. He also furnished a large amount of useful data especially in the hydrographic line. He was a most prominent member of the Conservation Association and his council was always of greatest service to that body. He was chief promoter of the project of having the

great conference of governors which President Roosevelt brought to the White House in 1908. He was secretary of the conference, guided its deliberations and prepared the fine volume of its proceedings. He was made a member of the Inland Waterways Commission when it was created in 1907 and later was appointed its secretary, an office in which he continued to the time of his death. He did a vast amount of work for that commission and much of its value came from his services.

McGee was greatly interested in our scientific societies and had a prominent part in their organization, meetings and administration. He was a member and frequent attendant at all the societies in Washington and the Historical Society owes its existence largely to his interest and energy. The National Geographical Society also had his aid in its inception and development and he edited its magazine for several years. After his active editorship ceased he remained an associate editor until 1908. He was president of the society in 1904 and 1905 and held other offices in its administration.

He was greatly interested in the Anthropological Society of Washington, serving as its president, and in 1911 he was also president of the American Anthropological Society. In 1902 he was vice-president of the Archeological Institute. He was one of the founders of the Geological Society of Washington and made many communications to it in its early days. He was one of the small group of geologists who organized the Geological Society of America and for many years he was editor of its Bulletin. This publication had many novel and admirable departures from old time methods and its form was copied by various other societies. In the earlier years of its existence he attended all the meetings of the Geological Society of America and frequently read papers. He was one of the original members of the Association of American Geographers and gave us two interesting communications at the New York meeting in 1906. In 1904 McGee was chairman of the organizing committee for the International Geographical Congress and he was appointed U. S. Commissioner to the International Committee of Archeology and Ethnology and senior speaker at the World's Congress of Arts and Sciences. He was given the degree of LL.D. by Cornell College in Iowa, in 1904.

McGee died at the Cosmos Club in Washington on September 4th, 1912 from cancer which began developing in the prostate region some years ago. The progression of the final stage of the disease was slow, confining him to his room and then to bed for about two weeks, and there were four days of coma at the end.

With characteristic originality and desire to advance science, McGee willed his body to the surgeons of Jefferson Medical College of Pennsyl-

vania and his brain to Dr. Spitzka. After the simple burial service at the home of his close friend, Gifford Pinchot, the body was shipped to Philadelphia in compliance with the will. At the same time there was forwarded to Dr. Spitzka the brain of Major Powell which had been in McGee's possession since 1903. There had been some good natured rivalry between the two as to the greater weight of brain; while McGee's brain weighed 1,410 grains Powell's was 1,488 grains, both far above the average of men in general but in the case of McGee slightly below the average of the brains of 100 eminent men in Dr. Spitzka's possession.

I shall not present a list of publications made by McGee for they can be found in the bibliographies of geology. They number more than 300. His most voluminous reports were on the "Lafayette Formation," "The Geology of the Head of Chesapeake Bay," "The Pleistocene Geology of Northeastern Iowa," "Potable Waters of the Eastern United States," "Siouan Indians," "Seri Indians," "Primitive Numbers," "Soil Erosion," "Outlines of Hydrology," "Primitive Trephining in Peru."

Of the personal side of McGee I need say but little. He was kind, gentle, generous and inspiring. His efforts were all for the best results and he strove unselfishly for the truth and the advancement of science. His mind was lofty and had a deep insight into the beauty of nature. His friendship was a never-ending fountain of help, good cheer and inspiration.

TITLES AND ABSTRACTS OF PAPERS

NEW HAVEN, 1912

Cyrus C. Adams.

Geographical Book Reviewing.

A summary of the writer's experience as to the varieties of comment that are most valuable in reviews of geographical works; with some remarks on occasional tendencies of reviewing that are not to be encouraged.

Henry G. Bryant.

A Canoe Journey in Southeastern Labrador.

Labrador, with its large unexplored areas and comparative accessibility, presents an attractive field for the pioneer explorer. The Atlantic seaboard is desolate owing to climatic conditions produced by the Labrador current.

The interior presents much more genial conditions and the timber and mineral resources are destined to attract increasing attention. The writer's third visit was made last summer (June-September) when he ascended the St. Augustine River 141 miles from the Gulf of St. Lawrence to Lynx Lake, its source on the Height of Land. Interesting tribe of Mountaineer Indians encountered at mouth of river. After much difficulty two Indian guides secured.

With experienced topographer, two Newfoundland canoemen and the natives referred to, party started in canoes up the river on July 12th. A river flowing in a narrow valley between ridges of Archaean rocks. Uniformity of sky line owing to glacial action. Difficulties of river travel increased, by desertion of Indians and physical disability of one of the canoemen. A ten mile portage. Difficulty of locating Indian route of travel. Source of river reached. Compelled to turn back here owing to continued illness of canoeman, when within ten days of the waters of Hamilton Inlet, the objective point of journey.

Results of journey: Considerable information regarding the topography and resources of a region previously unvisited by white men. Resulting map secured by prismatic compass survey checked by astronomical observations at twenty-one stations—is submitted as a definite, if modest contribution to knowledge.

W. M. Davis.

The Development of River Meanders.—Printed in full herewith.

James Walter Goldthwait.

Remnants of a Peneplain in the White Mountains of New Hampshire.

The well developed peneplain of southern New England, which is so extensively preserved on the uplands of Connecticut and Massachusetts, has never been traced northward far into New Hampshire and Vermont. Casual observations from this field have led to the inference that the old graded surface, here, was so much less completely reduced during the period of baseleveling, and so much more extensively and deeply carved away by rivers and by the ice sheet after its uplift that it is almost impossible to identify it.

While engaged in a study of the glaciation of the Presidential Range of the White Mountains, last summer, the writer found conspicuous fragments of a subdued mountain topography on the crest of this range. It seems very probable that this well graded surface represents the imperfectly worn down interior of the ancient peneplain which in Massachusetts and Connecticut is more fully developed. The smooth slopes of this old mountain form are contrasted with the bold outlines of the deep glaciated ravines in the sides of the range.

The probability that other remnants of this ancient graded surface will be found in other parts of northern New England was briefly discussed.

Douglas W. Johnson.

The Shoreline of Cascumpeque Harbor, Prince Edward Island.

The shoreline of Cascumpeque Harbor illustrates in an admirable manner certain features normally produced by the submergence of a maturely dissected plain, and presents additional phenomena which have caused it to be cited as the best example of recent submergence of a maturely dissected plain in the Maritime Provinces. The characteristics of the shoreline were briefly described, and the phenomena attributed to coastal subsidence were discussed. It was shown that forests have been killed by a local rise in high tide level, due to a change in the form of the shoreline, and to normal retrograding of an exposed shore under wave attack; that the remarkable Black Bank peat deposit affords no evidence of coastal subsidence; and that other evidence is more in accord with the theory of long-continued coastal stability.

Lawrence Martin.

The Filling of Fiords in Alaska.—Read by Title.

Subsequent to their excavation by glacial erosion a number of Alaskan fiords have been partly or wholly filled with glacial deposits. The nature of the glacial filling varies considerably along the following lines:—(a) submerged moraines, (b) delta building from the

side, (c) delta building at the head, (d) marine alongshore deposits supplied by distant glacial rivers, and (e) widespread bottom deposits.

The extent of this filling reaches 75 to 150 square miles in some fiords, as at Orca Inlet in Prince William Sound and at the head of Chilkat Inlet in southeastern Alaska. The thickness of such deposits which rise to or above sea level, amounts to at least 600 feet as near Katsehin River in Lynn Canal, in Orca Bay, Prince William Sound, and along Bering River near Controller Bay.

Of the several deposits, the submerged moraines, or moraine bars, are typically illustrated in Unakwik Inlet, Blackstone Bay, and Harriman Fiord in Prince William Sound, and in southern Russell Fiord in Yakutat Bay. The lateral deltas are well seen at the Stikine River in southeastern Alaska, the Katsehin River in Lynn Canal, and the Bering, Gandil, Nichawak, and Edwardes rivers in Controller Bay. The deltas and valley trains of outwash gravels at the heads of fiords are found at such places as Lowe and glacier rivers in Port Valdez, the streams from Mendenhall Glacier in Gastineau Channel, the Copper River in a former Copper River Fiord, and the Chilkat River at the head of Chilkat Inlet. The filling of fiords by tidal deltas, supplied by distant glacial streams and alongshore currents, is exemplified in Orca Bay and Orca Inlet in southeastern Prince William Sound. The widespread bottom filling of undetermined amounts of fine material carried in suspension and boulders dropped by floating icebergs is shown in Yukatat Bay, near Columbia Glacier, and in nearly all the fiords of Alaska.

Frank E. Williams (Introduced by Lawrence Martin).
Fiords of Southeastern Alaska.

The study of the fiords of southeastern Alaska has shown that the valleys have been occupied to a greater or less extent by glaciers moving in various directions, but the large ones flowed southward. While the "Inside Passage" appears to have a trend parallel to the mountain ranges, a study of the main fiord, Lynn Canal—Chatham Strait, shows that it does not coincide in direction for any great distance with the strike of the rock structure. The trend of this valley may be due to faulting, to rock structure in part, or to an inherited drainage from a former peneplained area. The fiords are preglacial valleys initiated and more or less developed by stream erosion but owe practically all of their present features to glacial actions. Much of the data for the study of the fiords was obtained from the U. S. Coast Survey Charts. The submerged contour maps based on this data show many hanging valleys, basins that have been scooped out below sea level, and some fiords whose channels continue across the continental shelf.

Isaiah Bowman.

Nivation in the Central Andes and a New Hypothesis of Cirque Development.

The physical effects of snow motion and the conditions under which motion takes place were presented. Curves were exhibited showing the bearing of these observations on the distribution of snow pressure and motion in a typical headwater alcove in the Central Andes. It is suggested that bergschrunds may be entirely absent in all stages of the glacial cycle without preventing the development of cirques.

George B. Roorbach (Introduced by W. M. Davis)

The Fault-block Topography of the Mohawk Valley.

The eastern Mohawk Valley is a type of fault-block topography developed in a region of initially south-dipping beds of sedimentary rocks overlapping resistant crystallines, that have been broken into blocks and tilted gently westward by several parallel north-south faults. Reduced in previous cycles nearly, if not quite, to peneplain conditions, the region is now occupied by the wide, mature valley of the Mohawk across which is a series of eastward facing fault-line escarpments, making the raised edges of the fault blocks. The main topographic features of one fault block are duplicated, with marked similarity, in each of the others, thus giving a series of repeating surface and drainage patterns. The fault topography has influenced, to a considerable extent, the economic conditions of the valley, especially the distribution of population, the character and distribution of soils, the distribution of forests, the location of water-power sites, etc.

W. M. Davis.

The Geographical Descriptions of the Llano-Burnet Folio of the United States Geological Survey.

The geographical introduction and the physiographic conclusion in the text of the U. S. Geological Survey Folios, taken with the topographical and geological maps, afford valuable descriptions of various parts of the United States. The inquiry is here raised as to whether the geographical introductions represent the present state of scientific geography as well as the following pages represent the present state of scientific geology. As an example for discussion the recently published Llano-Burnet folio was selected; it embraces a particularly interesting district in central Texas, regarding which an abundant knowledge has evidently been collected. Suggestions were made regarding terminology, method of presentation, and diagrammatic illustration, which, it is believed, would, if adopted, increase the high geographical value already reached in the present form of the folio.

F. E. Matthes.

Is the Delineation of Land Forms Capable of Being Rationalized? —Read by Title.

In the topographic profession it is not generally conceded that the portrayal of land forms on maps can be systematized in accordance with definite principles. It is held to be an art in which each man works with the light and talents that are given him. As a result there is a wide divergence in the character of maps drawn by different men. Scarcely two topographers agree in style of delineation. Maps made by different nations in regions having a physiographic kinship in some instances bear but little resemblance to one another, and this is as likely to be true of modern maps as of maps made several decades ago. While methods of survey have made rapid advances during the last twenty years, the art of topographic delineation has stood still. Its results to-day are likely to be no more trustworthy as representations of the relief than the topographic work of the last century. Considering that the delineation of land forms is by far the most costly part of the making of an original map, the desirability of progress in this direction will be plain. The problem has an economic side which alone would justify attempts at its solution.

Several years of tentative effort have strengthened the writer's conviction that there is a definite basis for a *rationale* of topographic delineation in physiographic science. While it may not be possible to eliminate entirely the personal equation in topographic work, it is believed nevertheless to be feasible to minimize the present divergencies by the recognition of certain fundamental principles.

Ellsworth Huntington.

The Shifting of Climatic Zones as Illustrated in Mexico.

In applying new tests to the theory of pulsatory changes of climate, the author last Spring made a visit to southern Mexico and Yucatan. Three types of evidence were found. In the first place excavations in the lacustrine plain surrounding the City of Mexico revealed an alternation of strata strongly suggestive of climatic pulsations. In the second place, alluvial terraces of the kind found commonly in the dry regions both of Asia and the United States are abundant in Mexico, and apparently can be explained only as the result of alternations between dry and moist periods. Finally in Yucatan a new and especially interesting line of evidence was found. Some of the chief ruins of that region are located in places where the forest is apparently too dense and luxuriant to permit of extensive habitation. This seems to indicate that in general the climate of the present is moister than that of the past, a conclusion directly contrary to that indicated in regions farther north. This seems to

suggest a shifting of climatic zones in such a way that subequatorial rains are now abundant in places lying poleward of their limit at some previous time. Such a change may be explained as a shifting of all the climatic zones from the pole toward the equator.

Alfred J. Henry (Introduced by R. DeC. Ward).

Secular Variations of Precipitation in the United States.

Owing to the vast extent of territory involved, and to the absence of actual observations of precipitation over a great portion of it, especially in the seventies and early eighties, a discussion of the secular variation of precipitation in the United States is beset by many difficulties. The Rocky Mountains evidently form a dividing line between two essentially different types of rainfall. East of the Rocky Mountains there are also several different types of precipitation. The quantity of rain or snow which falls on the areas represented by these types depends in large measure upon the varying weather conditions, and the latter in turn are subject to the control of the general atmospheric circulation. When therefore we combine in a single unit the precipitation of the whole country we reach a result that is difficult of interpretation since negative departures in one region may be offset by positive departures in another, and vice versa. Notwithstanding the foregoing, the evidence seems to point to a maximum of precipitation in the United States in the middle seventies which extended well into the eighties. The period of abundant rains was broken, however, by several years of light rainfall. Another maximum, although less pronounced, occurred between the years 1901 and 1906, the year 1903 however, being dry, and finally a third maximum occurred in 1909 only to be followed in 1910 by one of the lightest annual rainfalls recorded in the last quarter of a century. The length of the intervals between periods of light and heavy precipitation, respectively, is quite irregular. The periods themselves may be confined to a single year, or they may extend over three or four years. The general tendency, east of the Rocky Mountains in recent years, has been toward a diminished rainfall and this diminution has been much more pronounced in some districts than others. These special cases were discussed in some detail and the conclusion reached that the cause of the diminution is to be sought in the general rather than the local movements of the atmosphere.

Robert M. Brown.

Final Report of the National Waterways Commission.—Printed in full herewith.

Sumner W. Cushing.

Some Important Coastal Plains in Japan.—Printed in full herewith.

Isaiah Bowman.

Lake Titicaca and the Rivers of Tiahuanaco.

A review was given of current opinions concerning the former greater size of Lake Titicaca, and the facts upon which they are based presented. The so-called evidence of former great extent is not valid. The lake has suffered only a slight reduction and never had a connection with Lake Minchin, the great lake that once occupied the Poopo depression on the south. The physical history of the basin and relation to megalithic ruins at Tiahuanaco were outlined. A summary of the assumption as to change in lake level affecting the site of the ancient city and of the effects of climatic changes on the highland people was made. Part of climatic change is due to regional uplift.

F. V. Emerson.

The Ozark Border and its People.

The Ozark Region in Missouri is a dissected plateau consisting of a strongly dissected center, a moderately dissected plateau-like area and the border where the Ozarks merge with the western prairies. Miller County, the area described, belongs on the whole to the moderately dissected plateau region. Topographically it consists of two areas: the Osage Valley passing through the north central part has a narrow flood plain flanked on either side by deeply dissected zones, the "River Breaks," eight to fifteen miles wide; on either side of the Valley are sharply rolling areas known locally as the "Prairies."

The distribution of population, farm products and values, and, in some degree, traits of the people are influenced primarily by soil types, the means of communication being equally available for much of both areas. Practically all the soils are derived from a cherty limestone except the alluvial soils, the dominant factor in the upland soils being topography. The weathered limestone yields a silt loam containing considerable chert; on the prairies the main type is this silt loam but on the slopes the finer material is removed leaving a more or less stony loam. At the foot of the slopes is a "shoulder" of colluvial material, the soil of which is much sought after for crop purposes. The productive farms are found on the prairies, the narrow flood plains and the narrow belts of colluvial material at the foot of slopes. Between the people of the "Prairies" and "Breaks" are great differences in prosperity and noticeable differences in other directions.

Charles C. Colby (Introduced by Mark Jefferson).

Some Geographic Influences in the Development of the Minnesota Driftless Area.

The influence of topography, soil, and drainage in the location and development of farms, transportation routes, towns, and manufactur-

ing industries in the driftless area in southeastern Minnesota was presented. Especial attention was given to the factors which are causing a change in the size, products, and problems of the farms and which are forcing the people in this region to know and practice the principles of conservation. A comparison was made of the present economic conditions in the counties in this unglaciated dissected area with other counties in the glaciated undissected sections of the state.

J. Russell Smith.

Tree Crops as a Control of Erosion.

Erosion is the most serious of all resource wastes. Plowing of rolling and hilly land is the greatest promoter of erosion. We need crops that grow without plowing. Some fruit and nut-yielding trees meet this requirement. The adjustment of agriculture to resources and the preservation of the resources demand a new agriculture dependent on trees rather than on tilled grasses. This holds the possibility of doubling, or more than doubling the food supply of the United States and stopping our greatest resource waste.

F. P. Gulliver.

Chestnut and Man.—Read by Title.

Chestnut wood has been used in this country for a great variety of purposes, and its abundance in our forests has been an important factor in the rapid development of settlements along the Atlantic coast from Maine to Alabama. The ease with which the tree is felled, the great variety of uses to which the wood can be put, its rapid growth and often increased value as sprouts over seedlings, and its vigorous growth notwithstanding its susceptibility to various diseases make it of great geographic significance to man. To-day man is beginning to realize the great reduction in the cost of living from converting almost valueless sprout lands on mountain sides into great food producing areas. The Sober farm near Paxinos, Pennsylvania, with its two square miles of chestnut growths is a magnificent conservation example to the American people.

Mark Jefferson.

The Geographic Distribution of Culture in the United States.—Read by Title.

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Explanation of Plate II

a General view of Osaka Bay land forms. In the foreground is the intensely cultivated young coastal plain; beyond, the wooded mature coastal plain and in the distance the even-crested block mountains.

b From a spur of the mature coastal plain looking over the young coastal plain. An embanked aggraded consequent river is seen at the left extending across the plain. The main road is on the left embankment.

PLATE II

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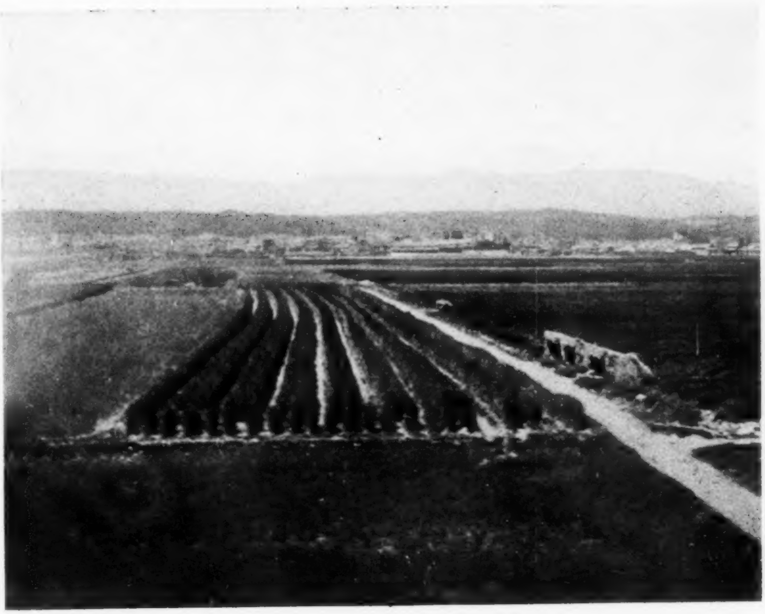

a

b

Explanation of Plate III

a On a slope of the mature coastal plain looking toward the mountainous oldland. The reservoir at the left receives water from a simple consequent river and irrigates the plots on the terrace slope and young coastal plain at the right.

b Looking down a simple consequent valley of the mature coastal plain on the east side of Osaka Bay. The village at the right distance is on the young coastal plain. The mature coastal plain reaches the sea at the right. Both plains end in marine cliffs, one of which is shown in Plate IVa.

PLATE III

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a

b

Explanation of Plate IV

a Marine cliff at outer margin of the mature coastal plain from which clay is being taken for making porcelain. A natural spring is seen at the center of the picture. It issues from above a heavy stratum of clay.

b Looking across an inland stretch of the young coastal plain, on which is situated a large chimneyless village, to the mature coastal plain at the left and the back of one of the block mountains at the right.

PLATE IV

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a

b

Explanation of Plate V

a Showing insequent dissection and lack of cultivation in the mature coastal plain spurs in the foreground and distance, in contrast with the young coastal plain below.

b Cultivated terraces in the less dissected outer portions of the fans near the inner margin northwest of Kobe.

PLATE V

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a

b

EXPLANATION OF PLATE VI

a Badland topography in the much dissected fans near Kobe.

b Excellent road construction and terracing in the mature coastal plain, with mountainous oldland in the distance.

a

b

Explanation of Plate VII

a Terracing on the mature coastal plain. At the base of the mature coastal plain fragment are caves cut in clay to serve as tool houses.

b Steep face of the block mountain oldland northwest of Kobe, showing the triangular facets.

PLATE VII

a

b

Explanation of Plate VIII

a From the upper surface of the mature coastal plain, looking across an extended consequent valley to a " bridge " of the mature coastal plain that connects its main body with the oldland.

b The young coastal plain occupied by the city of Kobe. Western influence is shown plainly in the houses in the foreground.

a

b

Explanation of Plate IX

a In Kobe, looking along an exceptionally broad street, toward the block mountain oldland. Note the even mountain crest suggestive of a prefaulting peneplain.

b In Kobe, showing a common method of transportation on the young coastal plain.

a

b

Explanation of Plate X

At the fall line back of Kobe, showing the Nunbiki waterfall, a tea house, and a common method of mountain transportation for passengers.

PLATE X

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Explanation of Plate XI

a A typical harbor such as is at the slightly drowned mouth of many of the rivers at the outer margin of the young coastal plain. Much of it is artificial and it is only deep enough to accommodate the native junks.

b A canal scene in densely populated Osaka.

a

b

Explanation of Plate XII

a A much dissected flank of the mature coastal plain. Note how painstakingly the Japanese have reformed the surface to make as much as possible highly productive, crowding the well graded road to its narrowest limits.

b In Yokohoma. The lower level is on the young coastal plain; the higher, on the mature coastal plain. The men's staircase, otokozaka, of one hundred steps, is here seen connecting the two.

PLATE XII

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a

b

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